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Chapter 4

THE ACTIVITY-BASED APPROACH

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1. Introduction

What is the activity-based approach (ABA) and how does it differ from the conventional trip-based model of travel behavior? From where has the activity approach evolved, what is its current status, and what are its potential applications in transportation forecasting and policy analysis. What have been the contributions of activity-based approaches to understanding travel behavior?

The conventional trip-based model of travel demand forecasting (see Chapters 2 and 3) has always lacked a valid representation of underlying travel behavior. This model, commonly referred to as the four-step model (FSM), was developed to evaluate the impact of capital-intensive infrastructure investment projects during a period where rapid increases in transportation supply were arguably accommodating, if not directing, the growth in population and economic activity of the post-war boom. As long as the institutional environment and available resources supported this policy, trip-based models were sufficient to assess the relative performance of transportation alternatives. It was clear from the beginning, however, that the derived nature of the demand for transportation was understood and accepted, yet not reflected in the FSM. The 1970s, however, brought fundamental changes in urban, environmental, and energy policy, and with it the first re-consideration of travel forecasting. It was during this period that the ABA was first studied in depth.

A wealth of behavioral theories, conceptual frameworks, analytical methodologies, and empirical studies of travel behavior emerged during this same period that the policy environment was evolving. These advances shared "a common philosophical perspective, whereby the conventional approach to the study of travel behavior ... is replaced by a richer, more holistic, framework in which travel is analyzed as daily or multi-day patterns of behavior, related to and derived from differences in lifestyles and activity participation among the population" (Jones et al., 1990). This common philosophy has become known as the “activity-based approach”. The motivation of the activity approach is that travel decisions are activity based, and that any understanding of travel behavior is secondary to a fundamental understanding of activity behavior. The activity approach explicitly recognizes and addresses the inability of trip-based models to reflect underlying behavior and, therefore, the inability of such models to be responsive to evolving policies oriented toward management versus expansion of transportation infrastructure and services.

In the next section, a summary and critique of the convention trip-based approach is presented, followed by an overview of ABAs, focusing on how these approaches address the various limitations of the conventional model. This is followed by a review of representative examples of activity-based approaches, including several perhaps best considered as contributions to understanding travel behavior, and several oriented toward direct application in forecasting and policy analysis. Some summary comments are then provided including an assessment of the future of both trip-based and activity-based approaches.

2. The Trip-based Approach

The conventional trip-based approach, exemplified in the four-step model (FSM), is best seen within the overall framework of transportation systems analysis, which positions travel demand and network performance procedures as determining flows which tend toward equilibrium with input from and feedback to location and supply procedures. In most applications, however, neither the location nor the supply procedures are fully integrated. In fact the demand procedure is represented by a sequential application of the four model components (trip generation, trip distribution, mode choice, and route choice) with only the last step, route choice, being formally integrated with the network performance procedures.

2.1 The Four-Step Model

The four-step model is the primary tool for forecasting future demand and performance of regional transportation systems. Initially developed for evaluating large scale infrastructure projects, the FSM is policy-sensitive with regard to alternative arrangements of major capacity improvements. It has not been effectively applied for policies involving management and control of existing infrastructure, and explicitly not to the evaluation of restrictive policies involving demand management.

Introduced piece-wise in the late 1950s and evolving fairly quickly into the now familiar four-step sequential model, the FSM has been significantly enhanced and modified since its first applications but still clings to the standard framework. That framework posits trips as the fundamental unit of analysis, then oddly and immediately severs and aggregates trips into production ends and attraction ends. This first step, *trip generation*, defines the intensity of travel demand (frequency by trip purpose) and the trip ends are independently estimated as functions of household and zonal activity characteristics. In the (usual) second step, *trip distribution*, trip productions are distributed in proportion to the estimated attraction distribution and estimates of travel impedance (time or generalized cost) yielding trip tables of person-trip demands. In the third step, *mode choice*, trip tables are essentially factored to reflect relative proportions of trips by alternative modes, and in the fourth step, *route choice*, these modal trip tables are assigned to mode-specific networks. The temporal dimension (time-of-day) enters in an ad hoc fashion, typically introduced after trip distribution or mode choice where the production-attraction tables are factored to reflect observed distributions in defined periods. In most applications, equilibration concepts are first introduced in the route choice step, with informal feedback to prior stages. Integrated location procedures are absent in most U.S. applications, and supply is introduced as a treatment (if we do this, what will happen?). A comprehensive presentation of the development and application of the FSM is provided in Chapters 2 and 3.

2.2 Limitations

In the conventional model, trip generation is the first step and effectively serves to scale the problem. With the structural absence of feedback to this stage, overall travel demand is fixed and essentially independent of the transportation system. The production and attraction ends of each trip are split and aggregated, parameters are estimated via independent models, and the basic unit of travel, the trip, does not again exist as an interconnected entity until the second phase of the standard process, trip distribution, produces aggregate estimates of total interzonal travel. It is only at this stage that any realistic measure of level-of-service can be introduced. These models explicitly ignore the spatial and temporal inter-connectivity inherent in household travel behavior. The fundamental tenet of travel demand, that travel is a demand derived from the demand for activity participation, is explicitly ignored. These factors are the primary reason why the effects of induced travel cannot be introduced in conventional models. Also note that with the lack of integration of land use forecasting models in the FSM process, future activity systems are essentially independent of future transportation networks.

It has been noted (perhaps by Kitamura) that trying to infer underlying behavior from the observation of only trips is somewhat akin to trying to understand the behavior of an octopus by examining only the individual tentacles. The weaknesses and limitations of trip-based models have been discussed by many authors (see McNally and Recker, 1986; USDOT, 1997); these limitations may be briefly summarized as:

(1) ignorance of travel as a demand derived from activity participation decisions;
(2) a focus on individual trips, ignoring the spatial and temporal interrelationship between all trips and activities comprising an individual’s activity pattern;
(3) misrepresentation of overall behavior as an outcome of a true choice process, rather than as defined by a range of complex constraints which delimit (or even define) choice;
(4) inadequate specification of the interrelationships between travel and activity participation and scheduling, including activity linkages and interpersonal constraints;
(5) misspecification of individual choice sets, resulting from the inability to establish distinct choice alternatives available to the decision maker in a constrained environment; and
(6) the construction of models based strictly on the concept of utility maximization, neglecting substantial evidence relative to alternate decision strategies involving household dynamics, information levels, choice complexity, discontinuous specifications, and habit formation.

These theoretical deficiencies appeared as most prominent in the inability of conventional models to adequately perform in complex policy applications, despite their acceptable performance in certain well-defined situations. In summary, trip-based methods do not reflect (a) the linkages between trips and activities, (b) the temporal constraints and dependencies of activity scheduling, nor (c) the underlying activity behavior that generates the trips. Therefore, there is little policy-sensitivity.

3. The Activity-based Approach

The activity-based approach was born of the same litter as the conventional trip-based model. The landmark study of Mitchell and Rapkin (1954) not only established the link of travel and activities but also called for a comprehensive framework and inquiries into travel behavior. Unfortunately, the overwhelming policy perspective of "predict and provide" that dominated the post-war economy led to the genesis of a transportation model that focused on travel only (the who, what, where, and how many of trips versus the why of activities), and the link between activities and travel was reflected only in trip generation.

Many authors (for example, Kurani and Lee-Gosselin, 1997) have attributed "the intellectual roots of activity analysis" to fundamental contributions from Hägerstrand (1970), Chapin (1974), and Fried et al. (1977). Hägerstrand forwarded the time-geographic approach that delineated systems of constraints on activity participation in time-space. Chapin identified patterns of behavior across time and space. Fried, Havens, and Thall addressed social structure and the question of why people participate in activities. These contributions then came together in the first comprehensive study of activities and travel behavior at the Transport Studies Unit at Oxford (Jones et al., 1983) where the approach was defined and empirically tested, and where initial attempts to model complex travel behavior were first completed.

Travel is one of many attributes of an activity. In the conventional approach, activity attributes such as the mode used and travel time consumed in accessing an activity are treated as travel attributes and are the focus of descriptive and predictive models (with most other activity attributes besides activity type being ignored). From this perspective, conventional trip-based models are simply a special case of activity-based approaches. Travel is essential a physical mechanism to access an activity site for the purpose of participating in some activity. While trip-based approaches are satisfied with models that generate trips, activity-based approaches focus on what generated the activity that begot the trip.

The activity approach began as a natural evolution of research on human behavior, in general, and travel behavior, in particular. Early criticism of the performance of the FSM did not serve as a major catalyst for activity-based research until the fundamental incompatibility of the FSM and emerging policy directions was realized. Rather, these criticisms placed significant focus on enhancing the FSM, primarily through the introduction of disaggregate models and equilibrium assignment. The overall framework was maintained and, effectively, institutionally reinforced. This is not to diminish the past and future potential of these contributions, since disaggregate models are often key components of activity-based approaches, but it serves to emphasize the overwhelming influence of institutional inertia, both in research and practice.

The fundamental tenet of the activity approach is that travel decisions are driven by a collection of activities that form an agenda for participation and, as such, cannot be analyzed on an individual trip basis. Thus, the choice process associated with any specific travel decision can be understood and modeled only within the context of the entire agenda. The collection of activities and trips actually performed comprise an individual's activity pattern, and the decision processes, behavioral rules, and the environment in which they are valid, which together constrain the formation of these patterns, characterize complex travel behavior. A household activity pattern represents a bundle of individual member's patterns which reflect the household activity program, the household transportation supply environment, and the constrained, interactive decision processes among these members. The household activity program, representative of the demand for activity participation within the household, is transformed through various activity demand and transportation supply allocation decisions into a set of individual activity programs, each an agenda for participation reflective of the constraints which influence the choice process. The actual scheduling and implementation of the program is completed by the individual, producing the revealed behavior of the individual activity pattern.

3.1 Characteristics of the Activity-based Approach

Proponents of the activity approach have been characterized by and benefited from a high degree of selfreflection, with significant discourse on not only what constitutes the activity approach but whether is a body of work with a sufficiently strong common philosophy to be deemed an "approach". This doubt came part and parcel with the diversity of theoretical, methodological, and empirical approaches employed. Holistic conceptual frameworks usually devolved to reductionist methodologies, adding little to what might be considered a theory of activity demand. But this profusion of concepts and methods merely reflected the exceedingly comprehensive target of attempting to understand the complex phenomena that is travel behavior.

Several interrelated themes characterize ABAs, and methods and models generally reflect one or more of these themes.

(1) travel is derived from the demand for activity participation;
(2) sequences or patterns of behavior, and not individual trips, are the relevant unit of analysis;
(3) household and other social structures influence travel and activity behavior;
(4) spatial, temporal, transportation, and interpersonal interdependencies constrain both activity and travel behavior; and
(5) activity-based approaches reflect the scheduling of activities in time and space.

The ABA takes as the basic unit of analysis the travel-activity pattern, defined as the revealed pattern of behavior represented by travel and activities (both in-home and non-home) over a specified time period (often a single day). These travel-activity patterns are referred to as household activity patterns and arise via the scheduling and execution of household activity programs. Individual activity programs result from some decision process which is assumed to allocate responsibilities in a manner consistent with a range of environmental, transportation, and household constraints. Activity programs are taken as an agenda for participation, or an individual's plan for travel and activity participation which after activity scheduling results in an individual (daily) activity pattern. Some activity-based models use tours (or, equivalently, trip chains) as the basic unit of analysis, an approach which reflects some, but not all, of the basic tenets of the approach (note that some full pattern approaches essentially represent patterns as bundles of tours).

3.2 Theory and Conceptual Frameworks

The criticism that the activity approach lacks a solid theoretical basis is akin to drawing a similar conclusion regarding the weather or the stock market, and reflects a lack of understanding of the incredible complexity of such phenomena, despite the universality that is also characteristic. While models are abstractions of reality, the reality in this instance is no less than daily human behavior, replete with all its vagaries. While attempting to understand such complex behavior is a valid endeavor, this statement of course begs the question of whether such a level of model complexity is necessary to fulfill the institutional goals of travel forecasting and policy analysis. At this point, it is only possible to conclude that the current level of abstraction evident in the FSM is clearly insufficient, and that some enhancement, and probably a significant enhancement of the abstraction, is required.

As a brief example of the complexity of the problem, consider a single-person household facing a day in which as few as three non-home activities need to be scheduled. Sequencing combinatorics, significantly compounded by scheduling (even in a small number of discrete time periods) and destination choice for some of the activities, and considering three travel modes and a half dozen route options per activity, leads to an order of magnitude estimation of 10^7 individual potential solutions. Various decision attributes such as interpersonal interactions, in-home activities, and various other constraints would reduce the alternative set, but larger households in activity and transportation systems with greater opportunities would explode the combinatorics. The complexity of fundamental human behavior clearly does not facilitate the development of theoretical constructs nor does it typically lead to consistency in empirical studies, with the result being a range of methodological approaches associated with a variety of partially developed theories.

The genesis of the work by Fried et al. (1977) was to develop an approach to understanding travel behavior. In addition to contributing to the establishment of the general themes of ABA (as discussed above), their work also examined the process of adaptation and the existence of stable points of reference (primarily social and role structures). The identification of stable points should be of particular importance given the methodological assumptions behind the conventional FSM. In that approach, forecasts and policy analysis are contingent on the existence of a stable structure which includes trip generation rates, travel impedance functions, and a variety of behavioral-based underlying parameters. While studies of the temporal stability of trip-based parameters exist, few conclusions have been drawn regarding similar stability in activity-based approaches. The theory proposed by Fried et al. (1977) suggests that role structures are not only stable but also strongly influence activity behavior. These structures exhibit some stability over stages of household life cycle. Preliminary evidence suggests that an activity pattern generation model also exhibits temporal stability, with the representative (or skeletal) patterns encapsulating most of the underlying parameters of conventional models.

While the activity-based paradigm may represent an original contribution from the field of travel behavior, associated theory has drawn as heavily from allied fields as the theory for trip-based approaches has. In fact, Fried et al. (1977) extensively reviewed the geographical, economic, psychological, and social science literature in developing their synthesized theory of travel behavior.

3.3 Adaptation in Activity Behavior

A recent recurring theme in activity analysis is the notion that individual behavior is governed by a series of adaptations. Fried et al. (1977) developed a comprehensive adaptation theory for activity and travel behavior. This theory focused on the concept of person-environment (P-E) fit, defined as an individual’s perception of how well the physical and social environment allows for the desired activities to be completed successfully. An individual may develop a daily routine that serves medium and long-term needs as dictated by a position in social space from where the individual’s activity program is derived. Fried et al. describe this positioning as a set of role complexes filled by the individual and representing different societal role classes associated with different activity types. If the environment makes the daily routine infeasible, then this P-E imbalance motivates the individual to adapt the routine to the current environmental reality. A short-term adaptation may involve route or departure time for a planned activity. The development of routines can be viewed as a heuristic problem solving procedure. Actively (re)scheduling repeated daily activities is unnecessary if patterns are found that are (at least) satisficing and that can be reused. Minor tweaking of routine patterns may occur frequently, but the cognitive effort necessary to actively perform a re-optimization must be balanced with the perceived benefits.

Lundberg (1988) introduced the concept of structuration, originally developed by Giddens. Structuration is both a top-down approach that constrains and shapes individual behavior as well as a bottom-up construct that is manifest in and transformed by individual actions. Lundberg's activity scheduling model is consistent with structuration theory in that it captured top-down structural effects (the relative accessibility of resources for particular activities) with bottom-up generative effects (an individual's desire or need to perform an activity at a particular time). The approach to modeling task-switching behavior was focused on the concept of arousal. An individual has an agenda of possible activities, for each which is defined the individual's bottom-up desire or need to perform that activity at a given time. A second function captures the accessibility of each activity as a function of the distance between the individual's current location and that activity's location (top-down structural effects). The individual's environment was represented as a simple urban space with a defined transportation system and activity locations. The bottom-up and top-down functions for the individual's current position in time and space were combined into a single arousal measure for each activity. Various heuristics were tested for deciding on the individual's current action, which can be interpreted as an attempt to find the best person-environment fit through the process of adaptation.

An individual forced to perform many short-term adaptations may be pressured into making a more dramatic environmental shift by altering positional anchors in physical or social space. For example, an individual can change work or residential location to avoid a lengthening commute.

4. Data

In the field of transportation research nothing is more valuable yet simultaneously more limiting to the validation of theory and models. In many applications, it is the constraints of time and cost which limit our ability to gather the data needed in research. In emerging research areas, however, the critical question is precisely what sort of data is necessary in developing and testing theory and models. This is perhaps most relevant in the study of travel behavior. The attributes of activity data are further discussed in Chapter 16.

Hägerstrand's (1970) space-time paradigm is elegant in its conceptual simplicity yet in measurement it is horrendously complex. Hägerstrand's model, as with the outstanding majority of all behavioral models, depicts what is conventionally referred to as "revealed behavior" but perhaps more correctly should be referred to as the "revealed outcome" of an unrevealed behavioral process. In fact, it is more probable that the set of rules and procedures that define such behavior will exhibit stability than the travel or activity patterns that result. Research is needed that establishes these rules, but there remains precious little behavior in behavioral models. Gärling et al. (1994) argued that such models are "confined to what factors affect the final choice, whereas the process resulting in this choice is largely left unspecified".

In recent years, conventional trip-based travel surveys have evolved into activity-based surveys. While this transition has improved the quality of responses, the range of information collected has not significantly changed. This in part is due to the need to collect data for conventional modeling purposes, and in part, perhaps, due to a lack of knowledge as to precisely what should be collected. It appears that, despite the claimed role of constraints on behavior, little is being collected regarding temporal, spatial, and interpersonal constraints of individuals and households. While the use of panel surveys, revealed/stated preference studies, and continuous monitoring of travel and activity via internet-based and remote sensing technologies, such as global positioning systems (GPS), will increase, the issue of what data is needed still must be resolved.

5. Applications of Activity-based Approaches

While the ability to reflect behavioral responses has improved in the FSM, the model system does not reflect the behavioral process of individual decision-makers, but rather attempts to reflect their aggregate response. Practitioners are primarily looking for improvements in, or alternatives to, the conventional 4-step model, while development efforts of activity-based models typically have the fundamental understanding of travel behavior as the primary goal. Practitioners, to a large degree, are looking for better means to answer existing questions. In the ABA, many entirely different questions are being asked. Therefore, current, imminent, and potential contributions of representative activity-based approaches to improving the state-of-the-practice are presented, together with an assessment of other work in activity-based modeling with perhaps less direct application but potentially greater eventual impact on travel forecasting.

5.1 Simulation-based Applications

The pioneering work of Hägerstrand (1970) in establishing the field of time-geography provided a comprehensive and unified paradigm for the analysis of complex travel behavior. An individual's choice of a specific activity pattern is viewed as being the solution to an allocation problem involving limited resources of time and space to achieve some higher quality of life. Hägerstrand approaches the problem by analyzing the constraints imposed on an individual to determine how they limit possible behavior alternatives, a view which represents a break from the more traditional viewpoint in which behavior is described via observed actions.

The means of illustration utilized by Hägerstrand was that of the now familiar three-dimensional space-time model, in which geographical space is represented by a two-dimensional plane and time is defined on the remaining, vertical axis. This representation allows pattern definition in terms of a path through time and space. The location of activity sites together with the maximum speed an individual can travel in a given direction establishes the individual's space-time prism, the volume of which represents the full range of possible locations at which an individual can participate. Once an individual travels to a specific location, the potential action space for any subsequent activities will be reduced depending on the prior activity's duration. Hence, at no time is the individual able to visit the entire set of locations contained in, or any destination outside of, the prism. Lenntorp operationalized Hägerstrand's approach by developing a model that calculated the total number of space-time paths an individual could follow given a specific activity program (the set of desired activities and durations) and the urban environment as defined by the transportation network and the spatial-temporal distribution of activities. Lenntorp's model was the basis for CARLA developed as part of the first comprehensive assessment of activity-based approaches at Oxford (see Jones et al., 1983), both of which served as the prototype for STARCHILD (McNally and Recker, 1986; Recker et al., 1986). Bowman and Ben-Akiva (1997) provide a concise summary and comparison of several simulation-based and econometric ABA models as well as for trip- and tour-based models.

STARCHILD emerged from a project designed to examine trip chaining behavior, with the development of full pattern models positioned as the general case of tour-based models. STARCHILD sought to directly represent the generation and execution of household activity patterns via three comprehensive steps. First, it addressed the development of individual activity programs, reflecting basic activity needs and desires as well as elements of household interaction and environmental constraints. Second, it approached the generation of activity pattern choice sets from individual activity programs, reflecting the combinatorics of feasible pattern generation and a variety of cognitive decision rules for producing distinct patterns. Third, it specified a pattern choice model reflecting only those attributes consistent with the components of the theory. The framework integrated a wide range of decision rules in each facet, involving interdependencies in: (i) activity generation and allocation, (ii) potential scheduling and participation, and (iii) constrained preference and choice. The pattern generation component is an extension of the Lenntorp and CARLA models, and generated via enumeration sets of feasible patterns (that is, patterns reflecting all associated constraints). Subsequent modules provided means to classify representative patterns or to filter non-inferior patterns for subsequent analysis. The representative pattern concept differs from that used in many classification studies in that these patterns are representative of the patterns in the (feasible pattern) choice set for a particular individual, rather than being patterns representative of the aggregate behavior of an observed sample or population. The final stage of STARCHILD was a pattern choice model reflecting underlying attributes of each pattern, such as travel time to different activity types, waiting time, time spent at home, and risk of not being able to complete a pattern due stochastic effects of travel time or activity duration.

STARCHILD often has been referred to as the first operational activity-based model, but it was designed for research purposes and certainly not for general application. The primary weakness of STARCHILD remains -- it was designed to utilize data that, although critical to the theory of activity-based models, are still not typically available today. These data, basically the temporal, spatial, and interpersonal constraints associated with the Hägerstrand framework, was available for a single activity data set collected to investigate dynamic ridesharing. Although the model has full functionality without this data, it is believed that the combinatorics resulting from under-specification of actual constraints would be unwieldy.

5.2 Computational Process Models

Gärling et al. (1994) summarized the development of computational process models (CPMs), and included STARCHILD and its predecessors as early examples. They developed SCHEDULER, a production system that can be seen as a cognitive architecture for producing activity schedules from long- and short-term calendars and a set of perceptual rules. Ettema and Timmermans (1995) developed SMASH which has similarities to STARCHILD in data requirements and to SCHEDULER in process, but conducts a search where activity insert, delete, and substitute rules are applied to individually generate activity patterns.

These initial CPMs lead to the development of more elaborate model systems such as AMOS (Kitamura, 1996), an activity-based component of SAMS, an integrated simulation model system comprising land use and vehicle transaction models in addition to AMOS. AMOS was applied in Washington DC as part of a study focusing on adaptation and learning under travel demand management (TDM) policies. AMOS includes a baseline activity analyzer, a TDM response generator (using revealed and stated preference data), and rescheduling and evaluation modules. Although AMOS was designed with a rather specific policy application in mind and is not valid for general prediction, it nevertheless made a significant contribution in moving comprehensive ABA paradigms toward operation status.

ALBATROSS (Arentze and Timmermans, 2000) was the first computational process model of the complete activity scheduling process that could be fully estimated from data. ALBATROSS (A Learning-BAsed TRansportation Oriented Simulation System) posited a sequential, multi-stage activity scheduling process whereby the individual (a) develops a preliminary schedule that meets known static and dynamic constraints, (b) modifies that schedule during subsequent planning to resolve conflicts, and (c) modifies the schedule during its execution to deal with unanticipated events that change the feasible activity space and/or the demands to engage in activity. The system assumes individuals use a computational process of goal realization (daily program completion) given an activity space that is limited by a broad range of (essentially Hägerstrandian) constraints. ALBATROSS is a significant contribution to the state of the art and its on-going development continues to influence other activity-based approaches.

These CPMs and related simulation approaches explicitly recognize complexity with a holistic design with embedded reductionist components, rather than fitting "holistic" pieces into a reductionist trip-based model system. Thus, they represent one distinct promising direction for operational models but perhaps more importantly they provide a testbed for alternative conceptual frameworks for activity behavior.

5.3 Econometric-based Applications

As extensions of advanced methodologies first applied in the conventional trip-based model framework, econometric models hold many distinct advantages, including a well-established theoretical basis, a maturity methodology, and professional familiarity. Criticisms are primarily associated with the assessment of whether the implied decision process is valid for the complex problem at hand. Much of the early ABA work involved simultaneous equation, discrete choice, and statistical models of chaining behavior, activity choice, and related components of activity behavior. These methods were perhaps the first to allow for direct estimation of tour-based models.

The state-of-the-art in econometric approaches is the application of the Bowman and Ben-Akiva (1996) daily activity schedule system as part of demonstrations of the TRANSIMS model system (see below). In addition to the refreshing absence of a catchy acronym, the model system achieved the status as the first true activity-based model system applied in a regional model context. The model generates a daily activity pattern through application of a (heavily) nested logit model that reflects primary and secondary tours and associated characteristics. The proposed model structure was significantly reduced in scale due to estimation problems, primarily defined by combinatorics.

Other econometric applications include hazard-based duration models (see Chapter 6) and structural equation models. A representative example of a structural equation model is provided by Golob and McNally (1997). This model simultaneously represents the activity and travel durations of work, household maintenance, and discretionary activities of male and female couples, reflecting a range of exogenous variables. The model is of particular significance since it formally reflects household interactions in activity allocation (results suggest that not only does work travel time effect non-work activity duration, but the effect is negative and more significant for men than women). Structural equation models are effectively descriptive models and do not have direct forecasting application but nevertheless provide the means for a systematic assessment of the interrelationships across individuals, time periods, or other variables and thus hold promise with microsimulation approaches for introducing dynamics into activity-based models.

5.4 Mathematical Programming Approaches

The Household Activity Pattern Problem (HAPP) was developed by Recker (1995) in direct response to limitations in STARCHILD. The HAPP model is a variation of the "pick-up and delivery problem with time windows" common in operations research. As applied, households "pick-up" activities at various locations within a region, accessing these locations using household transportation resources and reflecting interpersonal and temporal constraints, and "deliver" these activities by completing a tour and returning home. Constructed as a mixed integer mathematical program, HAPP both provides a theoretical basic and explicitly reflects a full range of travel and activity constraints. An estimation procedure for the HAPP objective function, based on similarity metrics to infer the relative importance of spatial and temporal factors associated with out-of-home activities, uses a genetic algorithm for solution and positions the application of the HAPP model within a traditional demand context. While the overall model formulation is a robust and operational program that can be solved by generic solvers, initial applications have been limited to research applications and small data sets. Nevertheless, HAPP hold great potential to be extended both as a pure activity-based framework and also as a bridge to conventional discrete choice models of travel behavior.

5.5 TRANSIMS

TRANSIMS was developed by Los Alamos National Laboratories under USDOT and EPA support and was subject to a full scale demonstration in Portland, Oregon (for an overview see USDOT, 1994). TRANSIMS, as with SAMS, is an attempt to develop a comprehensive model system to replace the entire current transportation modeling paradigm. The front end of TRANSIMS is the activity-based model of Bowman and Ben-Akiva (see above), linked with a population synthesizer and integrated with a microsimulation of modeled travel behavior. The process of generating activity patterns for synthetic populations based on skeletal base patterns is similar to that proposed by McNally (1995) and can be compared to the process of adaptation used in adjusting a routine pattern to fit the environmental reality for a synthetic individual. From the perspective of activity-based models, TRANSIMS is significant since it formally reflects the need for such a behavioral representation in the overall model forecasting system. TRANSIMS, however, is dependent on extensive data defining the area being studied and has been very limited in application.

6. Summary and Future Directions

It has been argued that the conceptual clarity, theoretical consistency, and potential for policy application of activity-based approaches will lead to substantially greater understanding and better prediction of travel behavior. The inherent complexity of activity behavior and thus of any approach that hopes to capture this behavior has served as a significant and thus far insurmountable impediment to major advances, particular in the absence of a widely-accepted theoretical framework. Approaches that are more reductionist, particularly those with a high degree of compatibility with the FSM framework, are more likely to redirect the current model. To what degree such continued incremental change will be successful is unclear, but the risk of once again impeding the development of a truly behavior holistic framework is present. Of course, one must also consider the probabilities of achieving an internally-consistent holistic framework and whether such a framework will fulfill the necessary forecasting and policy requirements, not to mention whether the resulting detail would be somewhat illusory and whether modelers would lose sight of the forest for the trees.

6.1 Current Modeling Needs

There remains a lack of fundamental theory, but no shortage of alternative empirical constructs, on which to base new models and advances. While contributions have been made in most aspects of activity-based approaches, significant advances are needed in virtually all areas. Interrelationships on the interpersonal level and with respect to spatial and temporal constraints have not advanced much beyond preliminary results, in part due to data limitations. While substantial success has been achieved in tour-based models, full pattern-based models remain problematic.

In the short-term, it is most likely that modifications to the FSM will dominate model evolution. These modifications will minimally reflect fundamental advances in activity research, and may include tour and activity generation models, explicit treatment of the temporal dimension, and greater reflection of constraints on travel and activities. Internally consistent feedback may or may not be possible within the conventional framework, but this issue must also be addressed with activity-based models, particularly with incremental applications as components of conventional models. Activity-based frameworks such as that implemented in TRANSIMS may gain a foothold in practice due to its methodological familiarity with practitioners and fit within the conventional framework.

In the medium-term, it is likely that computational process models will achieve operational status, although questions remain regarding the practical application of microsimulation for forecasting and policy analysis. Further contributions to activity theory and conceptual frameworks are likely, contributions which will likely spur further methodological development. In the long-run, the potential of concepts such as self-organizing models, emergent behavior, and agent-based simulation is significant, but these approaches are most distant from the state-of-the-practice. Related modeling issues involving planning under uncertainty, dynamic assignment, vehicle simulation, and impact modeling (among many others) will influence and be influenced by advances in activity-based approaches.

6.2 Data Needs

At least until activity behavior is truly understood, more complex data, of better quality and quantity, is needed. The increasing ability to collect, store, process, and analyze comprehensive data sets will allow data mining and comprehensive research and evaluation. The use of surveys to assess the dynamics of change (panel surveys, direct monitoring of travel via advances in sensor technology) should greatly influence the development of activity-based models. Geographical Information Systems (GIS), internet-based survey research, real-time surveillance via Global Positioning Systems (GPS) and cellular technology, and the integration of Advanced Transportation Management Systems (ATMS) with travel forecasting models will provide new sources of data and facilitate model development.

6.3 Policy Applications

It is strange that the earliest activity-based work did explicitly address policy application (e.g., Jones et al., 1983) while much if not most of what has followed has been directed toward advancing the methodological state of the art rather than the state of the practice. Perhaps this is an artifact of model evolution in that partially evolved components contribute little to overall system functionality.

The current planning model dictated by policy and practice is essentially "predict and provide"; to some degree it has been a self-fulfilling prophesy. Future models will need to be sensitive to the impacts of such emerging issues as the growth in information technology, the general aging of the population, saturation in car ownership levels, and the sustainability of cities and transport systems. A current policy issues of interest is induced traffic, but care must be exercised to ensure that future model systems can distinguish between traffic that is essentially diverted (in terms of route, mode, destination, or timing) and that which is induced (new trips and activities in response to policy implementation). This relates to the issue of peak spreading (temporal rather than spatial sprawl), explicitly tied to a model that fully reflects the temporal dimension of travel.

6.4 Where We Are and Where We Are Going

The science and art of travel forecasting remains immersed in a period of transition, equally for the dissatisfaction with model performance as for the inherent interest in building a better mouse trap. However, the conventional modeling process is so firmly institutionalized that only a full replacement for the system, or modular and integrable component parts, could be accepted in practice and satisfy institutional constraints. This institutional inertia placed much of the onus for model improvement on academia, where well-defined contributions to the state-of-the-art often provide only marginal value to the state-of-the-practice or to any comprehensive innovation.

Much discussion regarding the activity-based approach is therefore focused on its potential as a full or partial alternative to the conventional 4-step model. This both limits the potential contributions of activity-based models and puts undue criticism on the success of these models in fulfilling the need for better forecasting models. The FSM had the fairly well-defined goal of forecasting the relative impact of major transportation infrastructure decision; and so, not surprisingly, its success in other policy applications has been quite limited. While a goal of the activity approach is to improve the policy sensitivity of FSMs, the initial and perhaps still greater goal is to get at the root of underlying travel behavior, whether or not this leads to improved forecasting models. The conventional model was developed in an application environment while activity models continue to be primarily the focus of academic endeavors despite increased call from practitioners to fulfill legislative demands of transportation models. While arguments supporting ABAs have been embraced by practitioners, fully operational activity-based models simply do not exist and those model systems developed thus far only been applied in limited case studies (here, "operational" indicates a level of software development and application that results in general acceptance of the methods and models in practical field applications).

What is the status of the activity-based approach? There has been significant empirical work attached to a variety of conceptual frameworks, much of which is complementary but some of which is contradictory. The absence of formal theory has not gone unnoticed, yet it is tacitly accepted since it reflects the complexity of the endeavor. Resultant criticisms encourage researchers to constantly re-evaluate advances and to revise directions. Reviews of progress abound and well illustrate the evolution of the field as well as the repeated and unresolved themes on a theoretical level.

While continuing and perhaps greater government promotion of research will produce benefits, the problem may simply be too complex to readily formalize as a black box. While the approach promised an improved theoretical basis, there is still no cohesive theory. The few operational models have but incrementally addressed the primary goal of greater policy sensitivity. And initial claims of only marginal increases in data demands have been certainly overstated. Microsimulation and other approaches hold great promise from a research perspective, but it is unclear how easily such approaches, if successful, can be readily adapted for general application. Taken together, these factors suggest that no off-the-shelf activity-based model system is imminent. The growing faith that ABAs are not only real solutions but are also just around the corner is probably not realistic and certainly premature.

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