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An Activity-based Microsimulation Model for Travel Demand Forecasting

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Abstract

This paper summarizes the initial formulation of a micro-simulation model for activity-based travel demand forecasting that integrates household activities, land use distributions, regional demographics, and transportation networks in an explicitly time-dependent fashion. Intended to form the initial elements of an alternative to the conventional four-step transportation planning process, the prototype model incorporates an activity-based travel behavior model in a micro-simulation approach utilizing a Geographic Information Systems platform to manipulate survey, demographic, land use, and network databases.

An aggregate classification using travel diaries produces representative activity patterns which are specified implicitly in terms of temporal information, activity purpose, and sequencing. The classification also provides probability distributions of activity dimensions such as purpose and duration. Additional households are sampled and, based on demographic, land use, and network characteristics provided by the GIS, a target representative activity pattern is specified as are ambient activity densities. Activity characteristics such as purpose and duration are drawn from the distributions associated with the target pattern; trips are sequentially simulated based on a Monte Carlo approach of potential activity-specific destinations within a range of travel times from the prior and the home locations. The nature of the simulation is such that the simulated pattern, while maintaining the general characteristics of the target representative pattern, reflects the activity distributions and network characteristics of the household being simulated. The resultant set of activity patterns may be aggregated for any defined spatial-temporal limits.

The model provides an activity-based method for estimating dynamic, linked-trip, origin-destination demand matrices. Effectively replacing the generation and distribution components of

the conventional process, the model represents a potentially important step toward the development of alternative transportation planning methods.

1. INTRODUCTION

Travel, viewed in theory as derived from the demand for activity participation, in practice has been modeled with trip-based rather than activity-based methods. Trip origin-destination rather than activity surveys form the principle database. The influence of activity characteristics decreases, and that of trip characteristics increases, as the conventional forecasting sequence proceeds from generation to route choice, with concomitant increases in the level of mathematical sophistication yet little added policy sensitivity.

The inadequacies of the conventional transportation demand modeling process are well documented (McNally and Recker, 1987). In fact, significant funding from the Intermodal Surface Transportation Efficiency Act (ISTEA) recently has been directed toward the Transportation Modeling Improvement Program (TMIP), a four track effort to increase the policy sensitivity of travel forecasting procedures and their ability to respond to emerging issues. The TMIP effort, however, has been thus far focused on the tail end of the forecasting process, a result perhaps attributed to the specific technical capabilities of the TRANSIMS project team at Los Alamos National Laboratories (LANL) and the critical need to replace the air quality component of regional transportation models (as required under ISTEA and the Clean Air Act Amendments of 1990 (CAAA)).

The current modeling process, often referred to as the four-step process, is best viewed in two stages. In the first stage, various characteristics of the traveler and the land use - activity system (and to a limited degree, the transportation system) are "evaluated, calibrated, and validated" to produce a non-equilibrated measure of travel demand (or Trip Table(s)). In the second stage, this demand is loaded onto the transportation network in a process that amounts to equilibration of route choice only, not of other choice dimensions such as destination, mode, time-of-day, or whether to travel at all. Although this approach has been moderately successful in the aggregate, it has failed to perform in any relevant policy test, whether on the demand or supply side. Fundamental research is necessary in both the first stage and in overall linkages of the model system. The activity-based approach, which has been forwarded over the past fifteen years, provides a comprehensive framework for this work (McNally and Recker, 1987; Pas *et al.*, 1994; Stopher *et al.*, 1993)). A brief summary of characteristics of the conventional process sets the stage for advances forwarded by activity-based approaches:

Characteristics of the Convention Modeling Process

1. trip-based versus activity-based
2. un-linked daily household trip generation rates applied with zonal demographics to expand to zonal trip-ends
3. distribution of un-linked trip ends accomplished via aggregate interaction models with general network impedances
4. conventional 4-step process models network-level traffic effects via static assignment
5. all disaggregate spatial and temporal information (chaining and time-of-day) is lost

Characteristics of Activity-based Approaches

1. travel demand is derived from activity participation
2. activity participation involves generation, spatial choice, and scheduling
3. activity and travel behavior is delimited (or even defined) by constraints
4. linkages exist between activities, locations, times, and individuals
5. alternate decision paradigms are probable

After a brief summary of ongoing research efforts, the proposed research effort is described.

2. BACKGROUND

Comprehensive and insightful reviews of the activity-based literature include McNally and Recker (1986), Kitamura (1988), Jones *et al.* (1990), and Axhausen and Garling (1992). Interest within the United States has peaked in recent years due to new Federal policy and funding from the Clean Air Act Amendments of 1990 (CAAA) and the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) which initiated the Travel Model Improvement Program.

2.1 Travel Model Improvement Program (TMIP)

In the past three years, the US Department of Transportation supported four projects to examine how transportation planning models could and should be improved to properly address both the impacts of new transportation technologies and the need for real policy sensitivity, particularly relative to air quality considerations (Spear, 1994). Three of the four proposals recommended that trip-based methodologies be replaced by activity-based approaches, two of which also proposing

microsimulation models; specific behavioral assumptions, proposed methodologies, and data requirements varied across the proposals. Each of the proposals, however, lack a comprehensive plan to move from theory to operational status, a characteristic which is unfortunate yet expected of attempts to capture the complexity of travel behavior. In his review of the proposals, Spear (1994) recommends continued work with activity-based microsimulation approaches, the development of dynamic assignment methods, and basic research on data management and integration via a Geographic Information System (GIS) platform.

These research proposals are noteworthy in not so much their presentation of new theories and approaches but in their synthesis of the state-of-the-art into a comprehensive framework. It must also be noted that such a comprehensive framework has been recognized and developed by many authors at numerous times throughout the development of activity-based models. It is quite probable that, with the exception of the integration of advanced computational aspects, the development of the existing four-step planning paradigm proceeded from a similar framework. Computational constraints have limited the development of better models and the testing of comprehensive theories. Most of the albeit significant results of twenty years of activity-based research has been necessarily reductionist leading to the oft-quoted claim that the approach is "fragmented and lacking a sound methodological foundation" (McNally and Recker, 1986).

While USDOT was assessing directions, they were simultaneously funding an extensive modeling effort to increase the policy sensitivity of existing models and to redesign the forecasting process via the Travel Model Improvement Program. This four track effort was developed to (1) improve existing procedures to insure consistency, (2) to elevate the state-of-the-practice to the state-of-the-art, (3) to complete major research and development toward a new forecasting paradigm and model, and (4) to improve data collection and management. The major production task of TMIP is the TRANSIMS project.

2.2 The TRANSIMS Research Program

The TRansportation ANalysis and SIMulation System (TRANSIMS) is being developed at the Los Alamos National Laboratory as part of the multi-track Travel Model Improvement Program (TMIP) sponsored by the U.S. Department of Transportation and the Environmental Protection Agency. The TRANSIMS project is a major effort to develop new integrated transportation and air quality forecasting procedures to satisfy the Intermodal Surface Transportation and Efficiency Act and the

Clean Air Act Amendments. The need for such models have become amply evident in recent years, as the deficiencies of conventional transportation planning models have been amplified in several instances, including lawsuits against Metropolitan Planning Offices. CAAA air quality concerns appear to be a prime determinant of the bottom-up revisions currently underway; activity-based analysis, a top-down approach, coincides in concept and scope with those components of TRANSIMS just actively underway.

TRANSIMS deals with individual behavioral units and predicts trips for individual households, residents, and vehicles rather than for zonal aggregation of households as done in conventional planning models. Such activity-based trip generation is followed by microsimulation of the resulting traffic in the transportation network to predict the performance of the individual vehicles and of the traffic/transportation system. The detailed simulation, in comparison with simplistic and unrealistic aggregate link cost functions used in conventional models, provides increased accuracy in prediction of environmental impacts (e.g., emissions) and travel times.

A hybrid simulation technique is being developed in TRANSIMS. A major caveat of TRANSIMS is a completely different approach in which nothing is assumed to be in equilibrium. A large metropolitan area would be modeled with fast running cellular automata (CA) simulation models with interfaces to much more detailed simulation of specific corridors and local networks. A major difficulty being addressed in the hybrid simulations is matching the detailed simulation requirements with the leanness of the fast-running CA simulation.

3. PROPOSED APPROACH

In parallel to recent initiatives identified above, a reformulation of the STARCHILD model (McNally and Recker, 1986a, 1986b) has been proceeding in several directions. A dynamic simulation version of STARCHILD has been developed and is being tested and Recker (1995), building on the STARCHILD paradigm, has developed a mathematical programming formulation that provides an explicit optimization framework for predicting household activity patterns. The prime impetus for the proposed modeling framework may be attributed to the need to produce dynamic trip tables to investigate the potential for Advanced Transportation Management-Information Systems (Jayakrishnan *et al.*, 1993). Such trip tables were viewed as the outcome of a re-envisioned planning process which would maintain trip linkages and temporal characteristics.

The proposed approach is directed toward the development of a micro-simulation model for disaggregate activity-based travel demand forecasting that integrates household activities, land use distributions, regional demographics, and transportation networks in an explicitly time-dependent fashion. Intended to form the basic elements of an alternative to the conventional four-step transportation planning process, the proposed approach incorporates an existing activity-based travel behavior model into a micro-simulation framework utilizing a Geographic Information System platform to manipulate the demographic, land use, and network databases and to interface with survey trip diaries. The approach is truly policy-sensitive; the integration of trip linkages and trip scheduling is implicit. Under this approach, the impacts of and the responses to air quality, network mobility, and land use policies can be dynamically simulated at the household level.

Developed in response to documented shortcomings in conventional travel forecasting, this approach builds on several years of prior research in the area of complex travel behavior. The state-of-the-art in pattern generation and dynamic assignment has advanced to the point where integrated model systems which can address the shortcomings of the conventional process are now possible. Indeed, the US Department of Transportation has initiated the Travel Model Improvement Program (TMIP) to address such developments. The contributions of the proposed approach include the development of a methodologies for estimating dynamic, linked-trip, origin-destination demand matrices and a potentially significant contribution to the development of alternative transportation planning methods.

4. METHODOLOGY

There are two major elements of the proposed framework. The first utilizes an existing activity-based model of complex travel behavior to generate household activity patterns. The second element utilizes these results, and via a proposed micro-simulation model, presents an alternate formulation of the conventional planning process. This micro-simulation model will itself comprise two integrated phases. The first phase serves to synthesize a desired number of fully specified individual activity patterns, replacing the generation, distribution, and mode choice components of the conventional model. In the second phase, the resulting dynamically specified trip tables serve as input into an existing dynamic assignment model. These models are integrated to allow for the introduction of level-of-service into the generation, scheduling, and execution of

individual activity patterns. After a review of existing alternatives for initial pattern generation and analysis, the proposed methodology for the two-phase simulation is presented.

4.1 Pattern Generation and Analysis

There are three distinct approaches to the generation of household activity patterns which can be integrated into the proposed framework:

1. Aggregate Classification
2. Disaggregate Generation, Classification, and Choice
3. Household Activity Pattern Problem Mathematical Program

The aggregate classification approach (Recker et al., 1983) was developed for the Department of Transportation in one of the first efforts to operationalize models of complex travel behavior. The approach involves a multi-attribute classification of observed daily activity patterns defined by small discrete time slices, the construction of representative activity patterns for population segments with similar pattern attributes, and the application of discriminant analysis to associate measures of land use and demographics to the identified patterns. The initial application utilized an Orange County sample from the 1976 Southern California Association of Governments (SCAG) Home Interview Survey, and was successful in classifying both representative patterns and those population segments typified by those patterns. The results were successfully applied in a variety of policy tests involving travel restrictions (such as gas rationing or operating limitations associated with electric vehicles).

The disaggregate generation, classification, and choice approach utilizes newly developed extensions to the STARCHILD Model System (McNally and Recker, 1986), generally acknowledged as the first and one of few operational activity-based transportation models. Activity programs identifying spatial and temporal constraints on planned activities serve as input to a pattern generation simulation, the results of which are classified into individual pattern choice sets. A subsequent procedure estimated choice probabilities of the pattern alternative. This approach is substantially more sophisticated than aggregate classification in that, for each individual, patterns are generated and a choice model estimated, rather than a direct classification over the population as a whole. The results are, therefore, sensitive to discrete changes in household constraints, stochastic variations in activity and travel sequencing and scheduling, and changes in the spatial and

temporal availability of activities.

Recent extensions to the STARCHILD modeling system include the incorporation of a mathematical programming formulation of the Household Activity Pattern Program (Recker, 1995) that represents an explicit optimization framework for predicting household activity patterns. Specifically, the household activity pattern problem (HAPP) is posed as a variant of the pick up and delivery problem with time windows (PDPTW) -- a problem that has received considerable attention in the operations research literature. This component of the model to be applied in this research addresses the optimization (relative to the household's utility function) of the interrelated paths through the time/space continuum of a series of household members with a prescribed activity agenda and a stable of vehicles and ridesharing options. Previous work (Recker, 1995) has demonstrated that this constrained optimization approach can be employed successfully for a broad range of household objectives, including various weighted functions of minimizing total household travel cost, total travel time, the risk of the inability to complete activities, and the delay in returning home incurred by trip chaining. To the extent that the model produces a well-defined, analytical global optimum to this complex problem, no other approach to operationalizing activity-based travel analysis currently exists. In the development of the mathematical programming component of the model system, a deliberate attempt has been made to maintain, to the extent possible, both the notation and structure of the well-known PDPTW in the hope that this would provide a conducive environment for future development and improvement. Although this approach has not yet been fully operationalized for application to policy analysis with aggregate data due to its reliance on extensive simulation capabilities, it has been explicitly developed to resolve limitations in the STARCHILD framework, offering a more complete representation of the generation of activity patterns.

Each of these components of the pattern generation stage of the STARCHILD modeling system provide similar information, albeit at significantly different levels of complexity and therefore with different degrees of reflecting the intricacies of actual pattern performance. Furthermore, each of these procedures utilize a sample of observed travel activity patterns. Aggregate classification produces population-level representative patterns. The pattern simulation module provides a set of detailed representative patterns and choice probabilities for each individual; the optimization module produces a single (and more completely specified) pattern for each individual in each household. The next step is to expand these results to the population, while maintaining the level of

information contained in the generated patterns.

A sample of neighborhoods was drawn based on the density of responses to a regional travel survey. A variety of land use and network indices were computed for each of these areas which were then cluster analyzed producing distinct neighborhood development categories (NDC). Significant differences were found between these NDC in terms of trip-based measures (such as average trip length and household trip rates) and activity-based measures (such as degree of trip chaining and activity transition probabilities).

4.2 Micro-simulation: Phase I

The purpose of this stage of the proposed approach is to expand the identified sample patterns to the population level. This step is also part of the conventional process, however, it is now applied by expanding non-linked trip generation rates by population-level demographics. Furthermore, the distribution of these non-linked trip ends is currently modeled via aggregate distribution models for 24-hour periods. It is clear that all disaggregate chaining and time-of-day information is lost.

A GIS-based micro-simulation approach is proposed which utilizes the patterns generated in the first stage as seeds for synthesizing population patterns. The specific simulation will depend on the nature of the pattern generation procedure. Assuming that the more elementary aggregate classification approach is initially selected, it will be necessary to, first, relate the identified representative patterns to demographic, land use, and network characteristics (see Recker et al., 1983), then secondly, identify the population distribution of similar household throughout the selected study area, and finally, to simulate the most likely activity pattern of each additional individual. This process assumes that the population-level representative patterns do indeed reflect underlying behavior, and that these patterns can be accurately associated with traveler characteristics; these assumptions have been tested and verified in earlier work. The additional step, the synthesis of additional patterns, is a key element of this proposal.

The general outline for pattern synthesis is as follows. The aggregate classification produces activity patterns which are specified by time-of-day in terms of activity type and mode (temporal information and activity sequencing are implicit). The classification also provides a probability distribution of activity type, mode, duration, etc. A household is selected and, based on demographic, land use, and network characteristics provided by the GIS, a target representative

activity pattern is also specified. The household location also determines the ambient density of activities. An initial activity, mode, and start time are drawn from the distribution associated with the target pattern. With these initial parameters, the trip is then simulated based on a Monte Carlo approach of potential activity-specific destinations within a range of travel times from the home location. Once determined, a second set of trip parameters is sampled, and a second trip is simulated based on the activity distribution and network characteristics relative to the prior destination. As a control, the average distance from the home location from the target representative pattern is maintained. This process continues until the entire patterns is specified. The nature of the simulation is such that the simulated pattern, while maintaining the general characteristics of the target representative pattern, reflects the activity distributions and network characteristics of the household being analyzed. Application of the STARCHILD approach would require modification of certain steps in this process, but would produce more clearly defined patterns. This simulation has been completed for hypothetical data by hand; it is estimated that operational software could generate these patterns quite efficiently, although the number of patterns needed to be synthesized to develop dynamic trip tables would result in considerable computer time (in the model calibration stage only).

The output of this micro-simulation phase is a set of population-level daily activity patterns. These patterns, the majority of which would be synthesized following an analysis of observed (survey diary) patterns, are fully specified with respect to all transportation, spatial, and temporal characteristics of travel. These patterns are equivalent, within the limitations imposed by simulation, to a 100 percent sample of population-level activity patterns. The aggregation of these generated patterns follows directly. The phase I simulation will address spatial variables in continuous space, thus, at aggregation, any spatial units can be defined. Similarly, time is treated continuously, thus, any number or length of time-dependent trip tables can be generated. Each trip table would only reflect those trips which are actually in motion during the specified period. In relationship to the conventional model process, the next stage would be assignment of the trip table(s) to the network. Dynamic trip tables imply dynamic assignment. In fact, much of the policy sensitivity of the proposed framework would be lost if path generation and assignment was not integrated into the model system. Never-the-less, the Phase I results themselves represent a significant advance in travel forecasting.

4.3 Micro-simulation: Phase II

Although it is possible to assign the generated dynamic trip tables via conventional assignment, more sophisticated alternatives exist. The dynamic trip tables may be assigned via formal dynamic path generation and assignment or via the TRANSIMS micro-simulation approach.

The conventional four-step planning process models network-level traffic effects through the assignment step. This approach has been well-recognized to be insufficient to capture environmental and energy-consumption effects of planning alternatives; primary reasons include:

1. the inability to capture congestion formation on network links using conventional link-cost functions (such as the BPR function) which monotonically increases with the flow
2. the difficulty in incorporating multiple objectives (equilibrium with low environmental impacts, for example) into the assignment step
3. the independent sequentiality of the conventional process requires feedback loops to achieve consistency; such feedback schemes may not necessarily converge (Boyce, 1994)
4. the inability of the four-step models to capture non-equilibrium network conditions anticipated under the Intelligent Transportation System (ITS) scenarios of the future
5. the improper treatment of trip linkages in static trip tables cannot capture trip chaining activities at any stage of the current process

These limitations provide the motivation to also reconsider the assignment process via a network micro-simulation approach, where the traffic effects are captured through detailed simulations. Such an approach was considered impossible in the past due to computational limitations; these very limitations were perhaps the primary rationale for adopting reductionist planning approaches of the past. Recent research in this area suggests that planning approaches based on network simulations are indeed now practical, due to the tremendous improvement in computer hardware capabilities. Dynamic assignment using detailed dynamic trip tables (which include chained trips in multiple time periods) is expected to soon be viable as well. A version of DYNASMART (DYnamic Network Assignment Simulation Model for Advanced Road Telematics) (Jayakrishnan *et al.*, 1993) will serve as the base for the phase II analysis and will be integrated into the proposed model system, both as a functional component for network simulation and as a means of verifying the Phase I research results. Although the model was initially developed for large network simulations for ATIS and ATMS, the simulation philosophy used in the program is particularly applicable to the objectives of the proposed framework. The model simulates the movement of

individual vehicles based on externally specified dynamic origin-destination matrices and initial paths, where the actual paths of drivers are based on modeled enroute decisions. The speeds on network links depend on prevailing link densities, hence congestion development, dissipation, and acceleration characteristics can be captured effectively. Among several application benefits of the model system are efficient state-of-the-art routines for network path finding and storage. The complete simulation of network signalization, freeways, ramps, and ITS strategies make DYNASMART a very flexible research tool. The model has been successfully applied with networks of a few thousand nodes and as many as 100,000 drivers; extensions to even larger networks for planning exercises are straight-forward.

An important aspect of the network simulation involves the development of dynamic equilibrium (or approximate equilibrium) paths. These paths serve as initial paths for simulated drivers; the simulation model does have stochastic behavioral rules that simulate their actual travel paths. This explains why the dynamic assignment does not need to provide an exact solution. Two approaches to develop these simulation inputs are proposed, both based on dynamic path-based assignment. The first is based on existing quasi-dynamic assignment models such as CONTRAM, the other is a more ambitious approach based on better dynamic assignment frameworks. The GIS shell is used to extract the network connectivity data during this step.

Path-generation Based on Existing Models

CONTRAM is a currently available dynamic assignment program that uses a somewhat approximate traffic modelling approach and an iterative procedure to find paths between O-D pairs, with the paths changing over time. While this is not a 'true' set of equilibrium paths, they are sufficient for initialization. Thus, the input to CONTRAM will be the Dynamic Trip Tables from the Phase I activity analysis, and its output will be a set of travel paths at various times.

Path-generation Based on Dynamic Assignment Models Under Development

The dynamic assignment framework that has been recently developed at UCI by Jayakrishnan has been based on a different approach than the conventional flow-based assignment. This framework uses the link densities as the optimization variables (note: the travel times are indeed monotonically increasing with respect to densities, as opposed to flow), and uses small time steps for multi-period assignment. In a related research project on faster algorithms (Jayakrishnan *et al.*, 1994), the necessary data structures and computational procedures for finding and storing path-based as

opposed to link-based solutions have been developed. Combining these procedures leads to a faster and more correct framework for dynamic assignment and path-generation.

The results of the dynamic assignment will feedback to the Phase I analysis. Theoretically, these results could be utilized in the activity pattern analysis component which precedes the two-phase simulation model, however, an investigation of the convergence properties of this approach would be difficult. Instead, the feedback will extend to the Phase I simulation where additional activity patterns are synthesized. Variations in travel times, as well as activity duration variations, are prime contributors to dynamic variations in pattern performance. The feedback of adjusted travel times (and new paths) will potentially effect the scheduling of portions of any pattern, therefore, impacted patterns will be re-synthesized from the point where the first temporal disturbance occurs. An investigation of this feedback and the implications on process stability and convergence represents a major research task.

5. PROPOSED DATA BASES

The availability of two extensive and somewhat unique databases plays a major role in the design of the model system. Both the Orange County database and the Portland, Oregon database have been brought on-line for initial model development and testing.

Orange County, California

- (a) Orange County subset of the 1991 SCAG Regional Origin-Destination Survey
- (b) 1990 Census Tiger files and tract demographics for Orange County
- (c) Orange County transportation networks and models (OCTAM II)
- (d) an ARC/INFO land use database from the Orange County Administration Office

Portland, Oregon

- (a) the 1994 Portland Metropolitan Activity and Travel Survey
- (b) 1990 Census Tiger files and tract demographics for Portland
- (c) Portland Metropolitan EMME/2 transportation networks and models
- (d) an ARC/INFO databases for land use, zoning, employment, etc.

The Orange County sub-sample of the SCAG Survey includes a 24-hour travel-activity diary for

each member over five years of age in 3400 households as well as conventional socio-economic characteristics of individuals and their household. The land use database and the census demographic information will be utilized in conjunction with the socio-economic profiles obtained from the surveys. The Census Tiger data files and the OCTAM model will provide the necessary transportation network.

The Portland database is unique in its inclusion of a two-day activity diary for each member of 3200 households (and comprehensive socio-economic characteristics of individuals and households); these diaries document all activities performed over a 48 hour period, including all in-home activities. As with the Orange County database, extensive GIS-based (ARC/Info) files include mappings of land use, census demographic information, and local employment estimates. A separate component of the Portland survey is a three-part Stated Preference Survey administered to a subset of the households which completed the activity diaries. Surveys of future preferences with respect to residential location, congestion pricing, and travel behavior have been completed and, although these data are not part of the proposed work plan, an extension of the current study building upon this data is planned. Although the Portland database is richer than that for Orange County, all of the data required in the comparative assessment is available in each data set.

Table 1. Comparison of Orange County and Portland Data Bases

Orange County (1991)	Characteristics	Portland (1994)
1-day Trip Out of Home 3200 random HHs -	Demand Data Base 1. Diary 2. Activities 3. Sample Size 4. Other	2-day Activity In and Out of Home 3000 clustered HHs Stated Preference
suburban auto dominated "sprawl"	Supply Data Base 1. Land Use 2. Transportation 3. Development	urban, suburban, rural multimodal controlled focused growth

The Portland sampling frame was in part determined by the nature of neighborhoods. Whereas the

neighborhood classification completed in the Orange County study was an objective output, the classification in Portland was a subjective input. Urban and suburban areas were classified in terms of land use mix, transit access, and a pedestrian environment factor, and this classification was used in drawing the household sample.

As a true activity diary, all in-home activities are recorded. The nature of the home as a determinant of travel behavior has of course been recognized, but not quantified. The trip purpose "return home" typically has been used to capture travel with no stated purpose other than one goes there when one is through traveling. It is hypothesized that the return home trip is driven by activity-demands in the household which influence the overall travel pattern. The constraints which are imposed by home activities and household interaction are hypothesized to be major influences in overall activity scheduling.

6. SAMPLE APPLICATION

To illustrate the proposed microsimulation framework, activity pattern classification results using Orange County, California data serve as input to the generation of new households and activity patterns. The actual data has been revised in the interests of depicting the operational aspects of the proposed model. An analysis of individual activity patterns by aggregate classification produced about a dozen distinct Representative Activity Patterns (RAP). When controlling for the influence of network structure and land use, a smaller number of RAPs can be associated with specific developments within the region. It is hypothesized that these RAPs, associated with a sub-area defined in terms of socio-demographics, network structure, and land use pattern, form a dimension upon which travel can be measured. While it is unlikely that an entire pattern is generated then executed without potentially significant variations in spatial, temporal, activity, and transportation dimensions, it is believed that such a base unit of travel behavior represents a significant improvement over the convention specification of household trip rates by purpose and selected demographic classification variables. Where the conventional model would generate unlinked trip ends then re-link origins and destinations via an aggregate spatial interaction model, the proposed approach generates full activity patterns containing representative linkages. It is hypothesized that the general characteristics of these linkages (activity type, mode, distance and travel time, scheduling, etc.) are representative of what similar individuals residing in similar sub-areas would also display. The specific sequencing, scheduling, and location dimensions of the pattern are

simulated based on distributions of these characteristics for each identified RAP.

The following procedure was manually executed for hypothetical individuals residing in Irvine, California. Figure 1 depicts three hypothetical RAPs which were identified in the actual aggregate analysis of Orange County activity patterns.

1. Select a sub-area (Irvine) from the region under analysis (Orange County).
2. Select a household location based on population density within the sub-area. Assign household and individual demographics based on census and survey data.
3. Select a target RAP based on the distribution of potential RAPs in the parent data set.
4. Based on sample distributions of the following dimensions, select target parameters for the activity pattern to be generated. For this example, each dimension can be defined by a mean and standard deviation (and minimum and maximum constraints).

Sample Parameters of Hypothetical RAP B (mean, SD)

Activity	Frequency	Duration	Travel Time	Distance
- work	(0.8, 0.3)	(8.0, 1.0)	(0.5, 0.1)	(6.0, 2.0)
- non-work	(1.2, 0.5)	(1.5, 1.0)	(0.3, 0.1)	(3.0, 1.0)

Time in hours, distance in kilometers

Simulate Activity #1:

Origin: home
 a) Activity type: Work
 b) Frequency(0/1): 1.0
 c) depart time: 7.50 am
 d) travel time: 0.4 hr
 e) duration: 7.2 hr
 f) trip distance: 5.7 km
 g) home distance: 5.7 km
 h) return home?: No

Simulate Activity #2:

Origin: Act 1 Work
 a) Activity type: Non-work
 b) Frequency (0/1): 1.0
 c) depart time: 15.10 am
 d) travel time: 0.2 hr
 e) duration: 0.9 hr
 f) trip distance: 2.3 km
 g) home distance: 5.0 km
 h) return home?: Yes

5. Figure 2 depicts the destination simulation approach. Using the GIS, all locations within the annulus defined by the mean and standard deviation trip distance are bounded. Using the GIS overlay of land use, population and employment density, and other appropriate trip attractors, the probability of a trip destination within the annulus is established (discrete sectors were utilized in the manual application). A random draw establishes the activity location. If the activity is not the first trip on a chain, then a second distance measure, distance from home, is used to construct a second annulus. The intersection of these areas defines the search space. If no solution is found, various simulation correction loops restart the process. This insures that the chain's ultimate return home trip reflects that observed in the target RAP.
6. If the simulation extends the chain, the process depicted for activity 2 is repeated. Otherwise, a return home trip is simulated followed by a determination of whether a complete activity pattern has been simulated or if further activities (new chains) are needed.
7. Other constraints may be imposed such as minimum and maximum participation times. If a simulated activity would violate a set constraint, then that activity would not be performed, and the simulation would proceed.

The simulation model is currently executed via a hybrid process where the initial classification and the GIS components are completed on separate platforms, with the transfer of information performed manually. The integration of system components is now underway given the apparent feasibility of pattern generation. There are, however, both many and significant issues to be addressed.

7. SUMMARY AND PLANNED RESEARCH

There are least three major questions to be resolved. First, will the proposed microsimulation approach work for real data sets? Can such an approach produce activity patterns which would be judged comparable to observed patterns? Preliminary simulations suggest that this is feasible. Second, given the ability to generate individual activity patterns (and extensions to household activity patterns), what is the potential that such a process can be effectively aggregated to reflect

regional trip tables. Assuming that the aggregation problem is solvable, the development of dynamic trip tables directly from the pattern results is straightforward since trip linkages and time-in-motion characteristics are implicit. And third, will the resulting trip tables be at least as good as current methods produce. Since the initial application of the proposed model was to front model systems such as TRANSIMS or DYNASMART, or simply to provide dynamic trip tables for dynamic assignment procedures, these questions must soon be resolved.

The proposed microsimulation provides a method by which to model trip linkages (as parts of fully specified activity patterns) as an alternate approach to the conventional model stages of trip generation and trip distribution. If successful, the microsimulation will not only be capable of replicating the existing model system in producing static trip tables, but will also provide dynamic trip tables. The parallels between the four-step process and the microsimulation approach are easily identified (such as in the destination choice component); these parallels are intentional and should facilitate the eventual application of this approach. This initial step toward a new model system builds upon activity-based approaches such as STARCHILD with goals of supporting such efforts as TRANSIMS. As several proponents of activity-based approaches have remarked, the limitation due to research fragmentation has produced the benefit of a multitude of research approaches. For what is an inherently complex phenomena, the modeling of travel behavior via these activity-based approaches holds significant promise.

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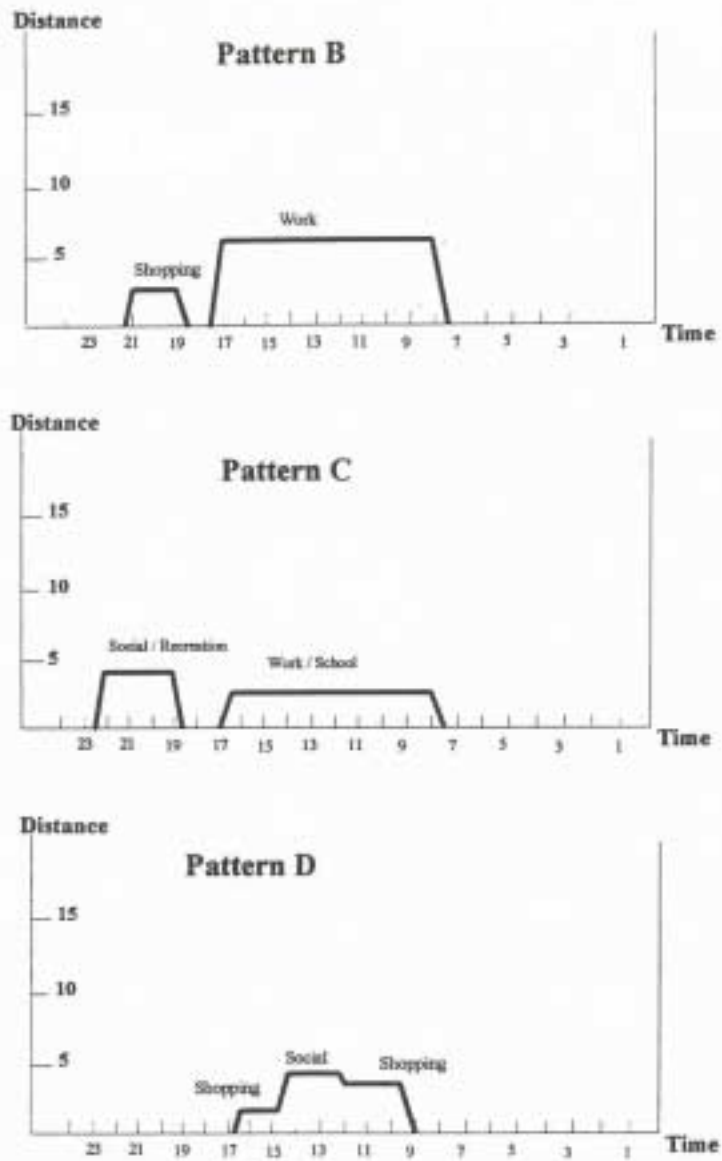


Figure 1
Target Representative Activity Patterns

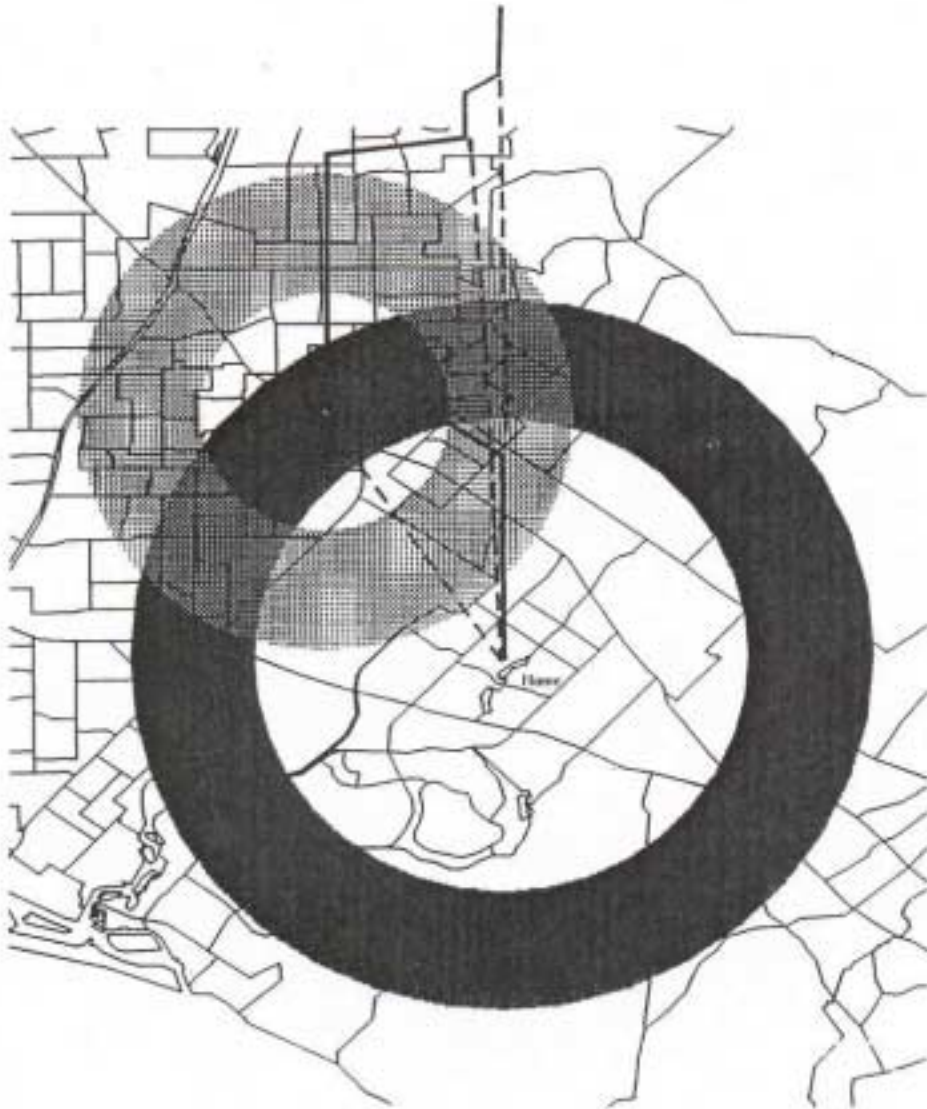


Figure 2
Simulation of Activity Destination