ACTIVITY-BASED TRAVEL FORECASTING: WHAT ARE SOME ISSUES?

KONSTADINOS G. GOULIAS

Assistant Professor
Department of Civil and Environmental Engineering
and Research Associate
The Pennsylvania Transportation Institute
The Pennsylvania State University
University Park, PA 16802
(814) 863-7926 - voice
(814) 865-3039 - fax
KXG2@PSU.EDU

INTRODUCTION

Models for activity-based travel forecasting methods are increasingly developed by researchers mainly in Europe and the United States in support of policy actions that cannot be addressed by existing modeling methods and forecasting applications (see Hofman *et. al.*, 1995, and Mierzejewski, 1996). Since the 1980s, when activity methods were considered as predominantly esoteric research approaches with very few applications (Kitamura, 1988, Jones, 1990), significant progress has been done in the three areas of data collection, modeling, and simulation that are the subject of this conference. In this paper a brief review of some issues that need to be addressed in the short and long terms are presented. Past unresolved forecasting issues and the policy context in the U.S. with an example from a program announced recently by the U.S. DOT are first provided. The paper continues with the basic definitions underlying activity-based forecasting methods and models and a brief description of accumulated evidence-knowledge that is found in the literature today. Specific issues for which some exploratory research is needed are also outlined. These issues are further developed and artificially categorized into short-term (in need of immediate answers and provision of evidence) and long-term issues that are presented as a straw man strategic plan for a successful activity-based travel forecasting system that could become the standard practice in the U.S. Specific issues to be targeted by the workshops in this conference are provided last.

NEEDS AND POLICY CONTEXT

Dissatisfaction with trip-based forecasting tools and attempts to move practice toward activity-based approaches predates the milestone legislation of the 1990s in the U.S. (Allaman *et. al.*, 1982). Indeed, issues such as forecasting the inputs to travel demand equations emerged as early as the first development and application of disaggregate choice models (Tye *et. al.*, 1982), which need detailed sociodemographic information at the level of a trip, an individual, and/or a household. Similarly, when aggregate approaches are used (e.g., at the traffic analysis zone), forecasts of sociodemographic information of the residents need to also be provided and many methods used in practice are gross approximations that produce many errors throughout the forecasting exercise (Hamburg *et. al.*, 1983). The 1980s research on this subject was partially in response to legislation such as the Federal-aid Urban System and the requirement for Metropolitan Planning Organizations to produce long range transportation plans, transportation systems management plans, and a list of transportation projects (the transportation improvement program-TIP). Public agency support (by Urban Mass Transit Administration, UMTA, today called Federal Transit Administration, FTA) for the Urban Transportation Planning System (UTPS) made the four-step procedure - trip generation, trip distribution, (trip-based) modal split, traffic assignment- the standard forecasting tool for evaluating large scale urban facility building in the 10- to 20-year horizons. The development of this tool took more than 30 years to mature (for example compare the 1950s applications in Detroit, Chicago, and Pittsburgh to the later UTPS-like systems in Seattle, Portland, and San Francisco among many others). Over time, however, the need for more accurate forecasting tools that contain richer analytical and forecasting instruments to address policy actions has been identified and documented (Bajpai, 1991, provides an example) and has yet to be satisfied. Indeed, emphasis was given more to the development of operational traffic engineering tools to study short term improvements (e.g., the TRAF-NETSIM, FHWA, 1994).

In the past five years, the need to examine new and more complex policy initiatives is becoming increasingly pressing since the passage of the Intermodal Surface Transportation Efficiency Act of 1991. The intermodal character of the new legislation, its congestion management systems that are mandatory for metropolitan areas with more than 200,000 people, and the taxing air quality requirements for selected U.S. regions motivate many forecasting applications. Substantial forecasting improvements can be clearly seen in a series of applications that have also been motivated by the Clean Air Act Amendments of 1990 (CAAA) that dictates impact assessment of transportation control measures and the creation of statewide mobile source air pollution inventories (Stopher, 1994, Loudon and Dagang, 1994, Goulias *et. al.*, 1993). Lack of funding for transportation improvement projects also motivates the need for impact fees' assessment for individual private developments, which in turn necessitates higher resolution for the regional council forecasting models and interfacing with traffic engineering tools that are recognized in state and local impact fee legislation (for examples see Levinson and Koepke, 1992, and other papers in the same volume).

This urgency for new forecasting tools is further compounded by the technology "push" under the general name of Intelligent Transportation Systems (i.e., bundles of technological solutions in the form of user services that attempt to solve chronic problems such as congestion, safety, and air pollution). Under these initiatives, forecasting models, in addition to long term land use trends and air quality impacts, need to also address issues related to technology use and information provision to travelers. Indicative of this are recent policy initiatives, such as "Operation Timesaver," which increase the modeling and forecasting demands for large metropolitan areas because of the shorter time frame for creating these policy analysis tools. Operation Timesaver was announced by U.S. DOT at the 1996 Transportation Research Board Annual meeting. The objective of this program is to achieve travel-time reduction(s) of at least

15 percent using Intelligent Transportation Infrastructure (ITI) deployed in 75 of the largest U.S. metropolitan areas within the next 10 years through an investment of $150 billion dollars. The intended infrastructure will contain smart traffic-control systems, freeway management systems, transit management systems, incident management programs, electronic toll collection on roads and bridges, electronic fare payment, railroad grade crossings that are integrated into the overall system, emergency response providers, and travelers' information systems. The U.S. DOT's vision is that with advanced technology investment we can create much more of the capacity we would have provided by building new highways (e.g., $10 billion investment in ITI is expected to provide two-thirds of the capacity needed). This public relations activity shows clearly what is expected of local regional planning agencies in terms of modeling and analysis. One of the goals of this initiative is to create transportation systems with measurable deliverable goals through a demonstration effort in which the future system is developed in stages and at each stage quantitative estimates of expected benefits need to be provided. This is something that the UTPS-like procedures were not designed for and obviously are unable to address. In a hypothetical "timesaver" metro plan we should expect metropolitan areas to provide access and better level of service using enabling technology (from the ITS portfolio of technologies). Since this operation is motivated by ISTEA and it is geared toward what is expected to emerge from the ISTEA reauthorization it is more likely that transportation demand and supply management will have a multi modal character and will be based on information provision and use by travelers and traffic managers.

Ultimately, ITI time saving initiatives enable people's freedom in time allocation (e.g., if 15% of their travel time is saved, they may use it for leisure and recreation activities or maybe additional work). Current travel demand analysis and forecasting practices are not sensitive to these shifts in time allocation because the temporal dimension in the UTPS-like procedures is totally absent (e.g., to compute the peak hour traffic flow gross factoring is performed on daily traffic forecasts) and under the best case scenarios partially present through some sort of post-processing.

Ongoing policy initiatives place more complex issues in the domain of policy analysis and forecasting to regional councils. In addition to the need for air quality modeling and transportation demand management impact assessment, regional councils need to also evaluate the impacts of new technologies, information provision, and pricing/financing strategies (e.g., tolls). To do this, their forecasting capabilities need to be more accurate and detailed in space by increasing the level of resolution of the current traffic analysis zones to capture much smaller geographic units. Consider for example the interesting exercise of estimating the regional effects of a corridor information management system and strategies that involve signal timing at intersections. They also need to predict traffic by time of day at time-slices that are much finer than the typical "AM-peak," "PM peak," and the "remainder of a day" types of daily segmentations. In addition to this increased resolution and fidelity of forecasting, other temporal scales need to be considered instead of the single time point forecast in the distant future. This emerges clearly from the need to consider the effects of staging in project development, which needs to be incorporated into the usual long range planning process and the submission of TIP projects with related impacts and comparisons in terms of costs, benefits, and cost effectiveness. This is particularly important for projects that attempt to influence travel demand and transportation supply at the same time.

Most important, however, there is a more basic need for data, models, and forecasting methods that have been developed from real-life experiences with some of these "new" policy actions. Projects for which impact assessments are needed are ongoing and will be emerging in the next two to five years from policy initiatives such as operation timesaver. It is clear, then, that for activity-based approaches one such initiative is an opportunity to demonstrate the superiority of activity-based data collection, modeling, and forecasting. While activity-based methods have the highest potential to address issues of this type, there is no hard evidence from field tests (e.g., validated and verified models that have worked in the regional council context). If activity-based approaches are to become successful in practice, we, as a transportation community, need to begin implementing and testing these models immediately using current projects as operational tests (very much like the use of technologies' operational tests in the Intelligent Transportation Systems arena).

ACTIVITY-BASED FORECASTING

An activity-based travel forecasting system is a system that uses as inputs sociodemographic information of potential travelers and land use information to create schedules followed by people in their everyday life providing as output, for a given day, detailed lists of activities pursued, times spent in each activity, and travel information from activity to activity (including travel time, mode used, and so forth). This output is very much like a "day-timer" for each person in a given region. A complete operational activity-based forecasting system does not exist yet. However, given the advanced state of research on the subject, we can envision a hypothetical activity-based forecasting system with the following as its basic ingredients.

Data on time use-allocation (Demand for Service): Information collected from persons on their current use of their time to participate in out-of-home and at-home activities and for travel from one activity location to another (called time allocation).

Data on activity opportunities and locations (Supply of Service): Information collected from places where people can actually pursue activities, including home. It also includes other attributes of activity participation such as availability, access, cost, etc.

Person and household time use (activity and travel) profiles: These are the models of time allocation that function the same way as the typical UTPS-like models for travel albeit in a much more complex form and providing more detailed information for analysts and planners.

An evolutionary engine (from t to t+x): Clearly the "snapshot" approach, a single time point in the distant future, to forecasting is surpassed. Alternate future scenarios are much more useful to decision makers because of the general trends they show rather than for their exact values of the forecast parameters. Some sort of mechanism that makes a region to evolve over time through the different stages of sociodemographic, and demand-supply changes is needed to depict the paths of, for example, traffic changes and reveals the instances at which policy intervention is needed. One such engine is called micro simulation.

Interface with other forecasts: The charge of forecasting regional needs is not limited to transportation. Economic development, housing, water supply, sewage systems, and recreation facilities are some other important areas that interface with transportation and they are within the planning domain of regional councils. Forecasts are also provided for these areas using a variety of methods (e.g., sociodemographic forecasting by cohort-based methods, housing needs by micro-economic methods, and economic development by macro-economic models). All these methods need to be interfaced together to at least provide consistent forecasts.

An activity-based forecasting system needs data for model estimation/calibration and simply as basic inputs. Following the typical subdivision of data and models into demand for service and supply of service, following are specific examples of data needs.

Demand Side:

1. Longitudinal and geographic information on time use/allocation (activities, travel, opportunity locations, activity participation durations, and so forth)
2. Sociodemographics (age, gender, employment status, occupation, and so forth).
3. Knowledge of opportunities and level of service offered to people by the activity locations and the system that brings either people to the activities (transportation) or the activities to people (telecommunication).
4. Use of technology and information (e.g., use of personal computers)
5. Household resource availability (e.g., car ownership, housing characteristics, telecommunication equipment ownership, etc.)

Supply Side:

1. Spatial and non-spatial inventory of activity opportunities (e.g., shopping and teleshopping availability by time of day)
2. Daily, day-of-the-week, and seasonal opportunity windows (e.g., periods during which specific activities can be pursued)
3. Networks of spatial and non-spatial activity opportunities (e.g., transportation and telecommunications networks)

Assuming, then, that data on demand and supply are available (see the “Data” workshop summary in this conference), the next ingredients are models that will transform the data inputs into specific policy action impacts through observed and postulated relationships. These basic components are listed below with a brief description:

Sociodemographics and time use profiles: These are functions that are able to depict how different people use their time differently.

Household members’ activity allocators: Task allocation within a household is one of the major determinants of behavior. These are the functions that show which activities are associated with which member of a given household. These allocators could be also extended to other social groups to reflect tasks and associated activities when people are members of organized or spontaneous groups (e.g., a firm and its employees, a neighborhood and its residents).

Activity & travel equations: These are the equations and routines that map specific activity pattern behaviors to specific travel behavior (for examples see Hamed and Mannering, 1990, Kwan, 1995, Recker, 1995, Ben-Akiva and Bowman, 1995, Ettema *et. al.*, 1995, Pendyala *et. al.*, 1995, Ma and Goulias, 1996, Golob, 1996, Golob and McNally, 1996, and Golob *et. al.*, 1996).

Spatio-temporal models of supply: This is a set of functions that perform the same mapping of time-use to sociodemographics in the demand side and are needed in supply to correlate geography with activity opportunity and ultimately predict the desirability of locations.

Residence-workplace relocation and time use: In the U.S. changing jobs and/or residence is a frequent phenomenon. In this process people go through stages of "cognitive disengagement" from the previous workplace and/or residence and phases of "cognitive engagement" with the new workplace and/or residence. As a result their activity and travel patterns go through changes that should be captured by the activity-based travel forecasting system.

Telecommunications-information and time use: Telecommunications are used today either intentionally or unintentionally to affect the ways people spend their time. For example, telecommuting has been proposed as a method to mitigate traffic congestion. In this forecasting system, models that represent the use of telecommunications and information by people to participate in activities and travel should also be included.

Lifecycle-lifestyle changes and time use: Lifecycle and associated lifestyle are important determinants of time use allocation by individuals and their households. The changes in lifecycle and concomitant changes in time use allocation need to also be reflected in the forecasting system in a similar way as it is done in travel demand.

Seasonal and day-of-the-week time use profiles: Time use may change dramatically within a week (e.g., a weekday versus weekend) but also based on seasons (e.g., consider the shopping and related activities people pursue during the period of Thanksgiving to Christmas in the U.S.). Models need to incorporate these fluctuations if forecasting is to be done for these periods of time that are usually excluded from the traditional UTPS-like procedures.

Long-term trends in time use: In addition to the usual source of information for transportation models (e.g., models from data collected on a representative day or data spanning a few years), we also need models that depict longer term trends. For example, to estimate models representing the changing roles and resulting time allocation between men and women and respective roles in society.

EVOLUTIONARY ENGINE

Given the data and models outlined above, a forecasting system needs also a routine that uses the data as inputs and in which the models are embedded to produce forecasts. In practice, these are a series of logical statements that given an input population in a region create evolutionary paths of change from a given time point to the next using computer software. We can call this a micro simulator because it operates at the level of a single microscopic unit (e.g., a person, a household, or a vehicle). It is a simulation because we numerically exercise a set of models for a given set of inputs to produce forecasts (as opposed to the use of a closed form and mathematically exact solution to predict the future). Lack of knowledge and the inherent randomness of human behavior dictates the need to design these systems with at least randomness in input components making the evolutionary engine a stochastic micro simulator (Law and Kelton, 1991, and for a more complete and focused exposition see Miller, 1996, in this volume).

An evolutionary engine attempts to replicate the relationship among sociodemographics, land use, time use, and travel. The causal links among these groups of entities can be extremely complex and in many instances unknown or incompletely specified. This is the reason that no closed form solution can be created for such a forecasting model system. In terms of capabilities, however, the engine needs to provide a realistic representation of person and household life evolution (e.g., birth, death, marriages, divorces, birth of children, etc.) and spatio-temporal activity opportunity evolution while at the same time it accounts for uncertainties in data, models, and behavioral variation.

INTERFACE WITH OTHER FORECASTING WORK

Many regional councils (MPOs) have made substantial investments not only on UTPS-based forecasting systems (e.g., software) and data to "feed" their models (e.g., travel diaries and detailed trip-by-trip mode-specific information) but also on training and education of technical staff and elected officials. On one hand, as expected there is some resistance to accept and adopt new forecasting tools that obviously threatens to replace not only the UTPS-like models but also UTPS "experts." On the other hand, however, there may be a place for these old-fashioned forecasting techniques (e.g., as a backup to the new methods). Independently of whether activity-based forecasting methods are designed as substitutes or complementary to the existing methods, before their consideration we need to identify specific gains that MPOs may realize by moving toward activity-based methods today (e.g., begin to think of transportation service provision as a service that should eliminate barriers from peoples' productive life). Indeed, from a time-use perspective new user-benefit measures emerge (Gershuny, 1994, Kitamura *et. al.*, 1996). These measures are much more realistic and understandable than the nebulous concept of level of service (e.g., volume over capacity on a link of a network). In addition to a planning focus shift that may require time, the use of existing data needs to be looked at carefully. For example, in the recent past, regional councils have engaged in data collection using travel diaries in surveys (one-day, two-day, etc.). The data from these surveys may be a good source of information for activity-based approaches that can be used to answer some of the policy questions MPOs face. In addition, no regional council has attempted to collect time-use data over time spans that are longer than two-days. Data from repeated travel diaries have been collected and, from the behavioral standpoint and resulting model formulation, substantial gains will emerge from their analysis (e.g., the Puget Sound Transportation Panel at the Puget Sound Regional Council). Similarly, time use databases exist in the U.S. and they cover many years providing a rich source of information for changes in behavior over time. Maybe, then, one way to transition into activity-based forecasting would be to formulate models using data from these secondary sources, to be incorporated into the UTPS-based forecasting systems.

One of the motivations for this conference is that, on one hand, research-since the 1980s when activity-based methods were simply research experiments-has provided us with some undeniable evidence of its potential, while on the other hand, we are still unable to assess the capabilities of activity-based approaches as forecasting methods that are able to replace the aging UTPS-like procedures. We know, for example, that activity-based forecasting is more realistic because it deals with the way people allocate their time, it provides temporally rich information (i.e., detailed schedules of activities at high resolution-minute by minute, hour by hour) that can be used by traffic simulation software, it is based on a more natural framework that is easier to explain to decision makers, and it supports the development of better cost and benefits service measures leading to better planning. From the developmental viewpoint, research has produced new estimating frameworks (see Axhausen and Garling, 1992) and the approach is theoretically rich allowing to examine more complex issues (e.g., Golledge, 1995). There are, however, many unknowns about activity-based forecasting. For example, there is no evidence about the accuracy/precision (or predictive capabilities) of activity-based models, the activity opportunity-supply data requirements have not been examined and assessed for feasibility, their interface with existing methods is absent, little information is available regarding model building and maintenance costs, their apparent complexity to non academic audiences is threatening, and tests of possible model transferability are totally absent.

If activity-based travel forecasting is to be used in the short-term, we need success stories with proof of concept applications (i.e., a showcase). Given the prolific research activity in this field, however, the need arises for an organized impartial, and independent inventory and assessment of activity data collection methods and activity-travel methods and models. When applicable this inventory should include an examination of an interface with UTPS (e.g., building on STEP development in Harvey and Deakin, 1996) and a study of early demonstrations such as in the Portland, OR, metropolitan area. The creation of an activity-based travel forecasting method should be preceded by field experiments with, for example, one or more purely activity-based forecasting systems compared to hybrid methods that use existing resources and improvements to the four-stage approach. In addition, micro simulation is well established in traffic analysis and seems to begin to be accepted as a source of sociodemographic forecasting data. These field tests can include micro simulation in the form of TRANSIMS but also other simpler and less hardware-software demanding methods for smaller problems. Since alternate approaches to solve the same or similar problems may lead to specialized applications (e.g., methods for large MPOs in non-attainment areas versus methods for small MPOs with seemingly no air quality problems), parallel streams of development seem a reasonable route. This is particularly important because it sets the stage for the long-term R&D program. Most important, however, given the experience accumulated in ITS with operational tests, an independent evaluation of these field tests should be done. This will provide important input for the long-term development of activity-based methods. Strong evidence that can provide a proof to healthy skeptics about the forecasting capabilities of an activity-based approach should be a **"showcase."** This could be the assembly of a variety of techniques and models that have the potential of providing undeniable evidence of superiority over existing methods. For example, the showcase should contain routines and models that predict sociodemographics using micro simulation, which is a proven technology. While micro simulation is needed for the “dissagregate” information necessary for activity-based models it also provides the information needed for the more aggregate UTPS-like models such as income and employment. It could also contain routines/models that represent the activity supply inventory for forecasting (e.g., using Geographic Information Systems to pinpoint opportunity locations). Again, this may have a dual use for activity-based models and for better UTPS-like methods that attempt to identify specific generators of traffic for equitable traffic impact fee determinations (see Chung and Goulias, 1996). Then, the usefulness of time use profiles can be demonstrated in terms of their evolution over time, e.g., supply changes as a result of normal fluctuation (morning versus evening) an/or as a result of policy actions (e.g., land use ordinances and zoning regulations). Critical to this demonstration is the validation of forecasting using repeated surveys of the same people and geographic locations. The last ingredient of a showcase and not the least is engagement of a regional council as an active participant in this process. Indeed, the Portland regional agency, which may be a good candidate for showcase, is an active player in activity-based forecasting and it is realizing some of the benefits of activity-based approaches.

One of the accomplishments of this conference (and of the TMIP program) may be a vision of one or more future activity-based travel forecasting methodologies. This longer term R&D program should consider: (1) Data collection and modeling programs; (2) policy analyses to support; (3) benefits, risks, and costs; and (4) outreach and training. More specifically, however, from the methodological viewpoint, attention needs to be paid on the role longitudinal activity surveys may play in developing new methods (e.g., there is no repeated over time - panel - survey that collects time-use data in the U.S. for transportation research). In addition, methods to compare models in terms of their predictive performance are inexistent or very rudimentary while this topic is an open debate in other fields. A subject related to this regards research needed to develop these methods together with model verification and validation. None of the existing forecasting methods, travel and activity-based, is able to address systematically and comprehensibly current policy problems. Indeed, there is no method that can compare transportation system management strategies to transportation demand management strategies in terms of air quality benefits. Also, future policy problems (e.g., impact of widespread use of cellular communication for trip planning purposes) need to be identified and targeted by new development research efforts. From a TMIP operations viewpoint coordination with land use research may lead to benefits to the activity-based forecasting development and land use research.

SUMMARY

Activity-based approaches are a necessity that emerged from recent legislation, unsatisfied technical needs accumulating for the past two decades, and technology applications in the U.S. and Europe. Current proposed approaches attempt to address new policy questions and chronic problems and frustration with the aging UTPS-based forecasting methods and the “times are right” for activity-based forecasting systems for many reasons. Knowledge about activity-based data collection is at a mature stage (see Richardson *et. al.*, 1995, Stopher, 1996, and Stecher *et. al.*, 1996), activity model estimation/calibration and related frameworks exist and have been implemented in various contexts, and long-term frameworks to be used for activity-based travel forecasting have been designed (e.g., Morrison and Loose, 1995, and Spear, 1994). In addition, evolutionary engines to perform long-term detailed forecasting based on stochastic micro simulation are available (Miller, in these conference proceedings). However, practical issues through demonstration/illustration of the methods remain unresolved largely due to lack of specific field-tests, which can be attributed to lack of focused funding. As a result early applications of activity-based methods are promising but incomplete and the need arises for one or more demonstrations that in turn can show evidence of the new method's superiority over conventional methods. One way to speed up the process, of introducing activity-based methods to regional councils' ongoing work, would be to integrate these new methods with existing forecasting work. In addition, many technology tests are under way throughout the U.S. and they offer a unique opportunity to develop and test activity-based methods. In light of this, then, this conference may need to address the following in the three parallel streams of workshops.

Data Issues: (1) Data Collection for forecasting (collection methods, secondary use of other data, inventories of databases) and (2) Data content and cost comparison with travel surveys and possible secondary use of other databases.

Model Issues:(1) Existence and availability of time use models (activity and travel) and (2) Model complexity, realism, clarity, and comparison in forecasting potential

(Micro)Simulation Issues: (1) Simulation and uncertainty treatment, (2) Sociodemographics-locational analysis - schedules and time use profiles, and (3) Evolutionary aspects.

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