# *Guidebook on Activity-Based Travel Demand Modeling for Planners*

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# 1. Introduction

Since the beginning of civilization, the viability and economic success of communities have been, to a major extent, determined by the efficiency of the transportation infrastructure. To make informed transportation infrastructure planning decisions, planners and engineers have to be able to forecast the response of transportation demand to changes in the attributes of the transportation system and changes in the attributes of the people using the transportation system. Travel demand models are used for this purpose; specifically, travel demand models are used to predict travel characteristics and usage of transport services under alternative socioeconomic scenarios, and for alternative transport service and land-use configurations.

The need for realistic representations of behavior in travel demand modeling is well acknowledged in the literature. This need is particularly acute today as emphasis shifts from evaluating long-term investment-based capital improvement strategies to understanding travel behavior responses to shorter-term congestion management policies such as alternate work schedules, telecommuting, and congestion-pricing. The result has been an increasing realization in the field that the traditional *statistically-oriented* trip-based modeling approach to travel demand analysis needs to be replaced by a more *behaviorally-oriented* activity-based modeling approach.

### 1.1 TRIP-BASED APPROACH

The conventional approach to transportation planning has involved the four-step trip-based methodology. The trip-based approach (also known as the Urban Transportation Modeling System or UTMS) uses individual trips as the unit of analysis and usually includes four sequential steps as shown in Figure 1: trip generation, trip distribution, mode choice, and traffic assignment.

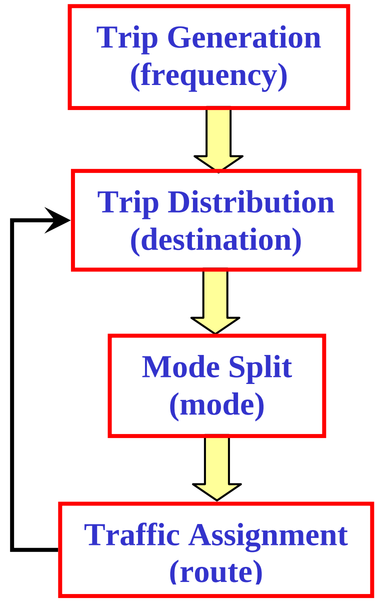


**Figure 1. Four-step trip-based approach**

A fundamental conceptual problem with the trip-based approach is the use of trips as the unit of analysis. Separate models are developed for home-based trips and non-home based trips, without consideration of dependence among such trips. Further, the organization (scheduling) of trips is not considered and the resulting inter-relationship in the attributes of multiple trips is ignored in all steps of the trip-based method. Take, for example, an individual who drives alone to work and makes a shopping stop on the way back home from work (refer Figure 2). The Home-Work and Work-Home trips in this scenario are not independent. So in the face of transit improvements, the trip-based approach would over-predict a shift to transit since such a shift may not occur in reality given that the person is constrained to making a stop on the Work-Home trip.

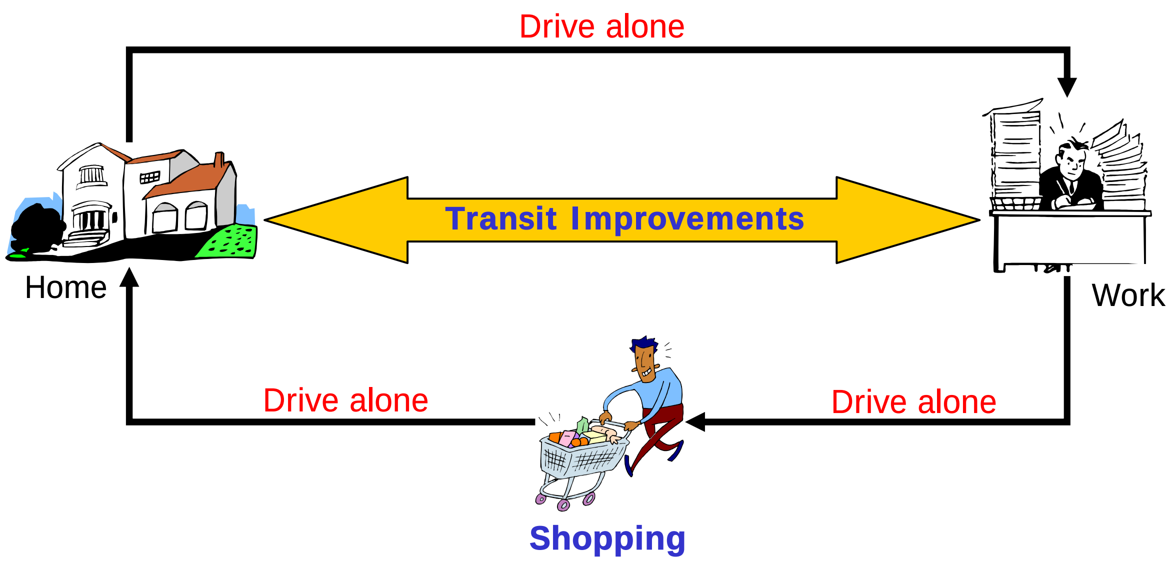


**Figure 2. Trip sequencing and inter-relationship in attributes of linked trips**

Another issue with the focus of the trip-based approach being the trips rather than the activities that motivate them is the difficulty in justifying this from a behavioral standpoint. It is unlikely that households will determine the number of home-based trips and the number of non-home based trips separately. Rather, the needs of the households are likely to be translated into a certain number of total activity stops by purpose followed by (or jointly with) decisions regarding how the stops are best organized. So failure to recognize any trip as a part of an overall daily scheme may cause the effect of a planning option to be overstated. For example, any policy that suppresses stop-making during the evening commute could result in the generation of another stop in the evening after returning home from work (see Figure 3). Such temporal redistribution of trips as a result of policy actions cannot be captured by trip-based methodologies. The trip-based approach similarly ignores spatial linkages between the trips made by an individual. It is important to acknowledge that the location of a stop in a multi-stop sojourn (or tour) is likely to be affected by the location of other stops on the tour.

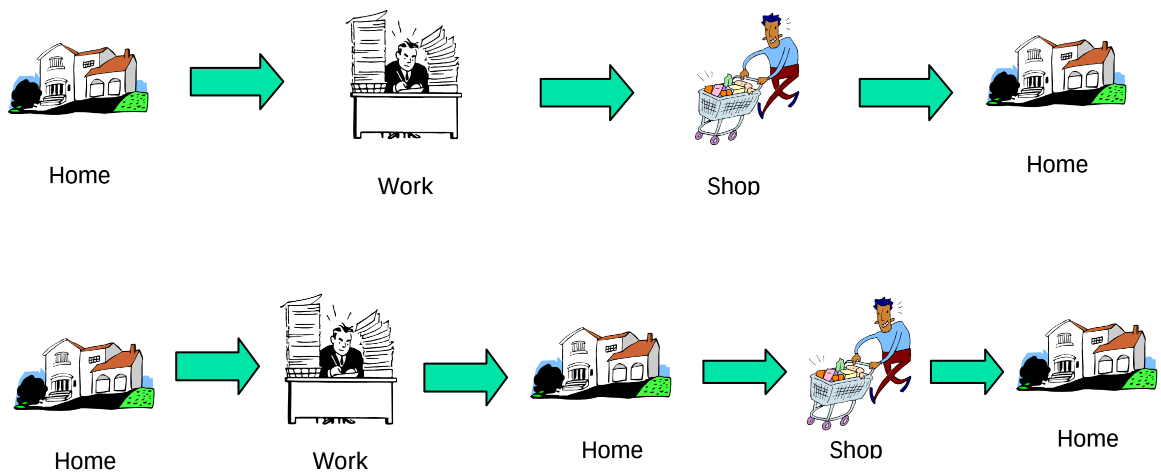


**Figure 3. Temporal substitution of trips**

Trip-based methodologies also ignore interactions among household members, thus failing to capture linkages among trips of household members. As a result policy actions (for example, a congestion pricing scheme) could have unexpected secondary effects as seen in Figure 4. Person 1 (the worker) might stop dropping the child off at school in the mornings but now person 2 (the non-worker) takes up that chore, and in addition to dropping the child off in the morning generates a shopping trip which might not have occurred otherwise. Another possibility is that person 1 might be completely absolved of both the drop-off and pick-up tasks. But now person 2 not only generates the drop-off and shopping trips in the morning, but also a pick-up trip in the evening (see Figure 5). Such complex results of policy actions cannot be captured by the simple and statistical approach of trip-based methods, which essentially work at the aggregate level and not at the more behavioral and disaggregate individual level.

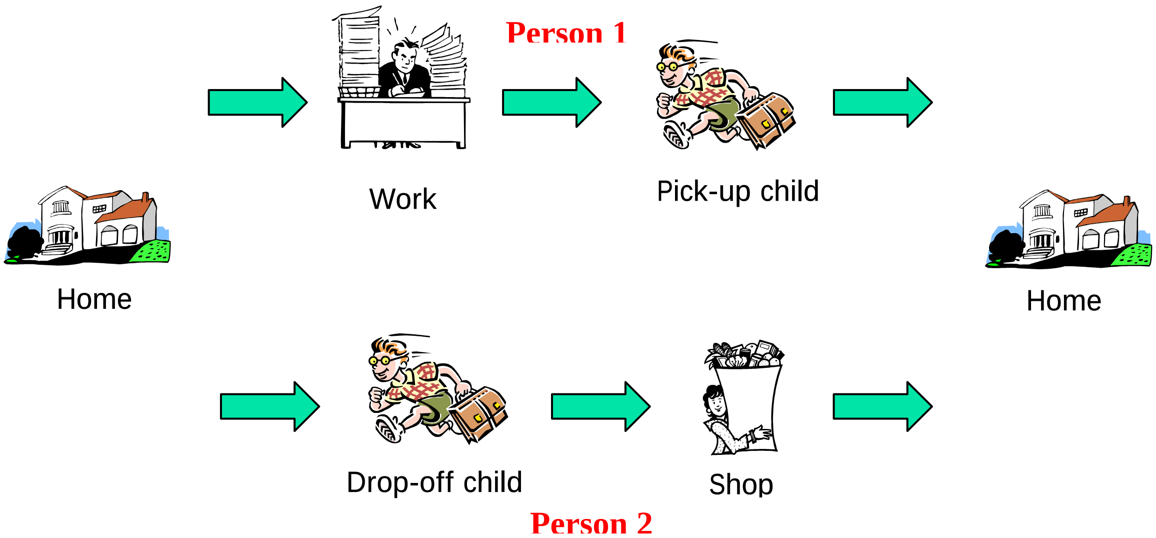


**Figure 4. Secondary effects of policy actions**

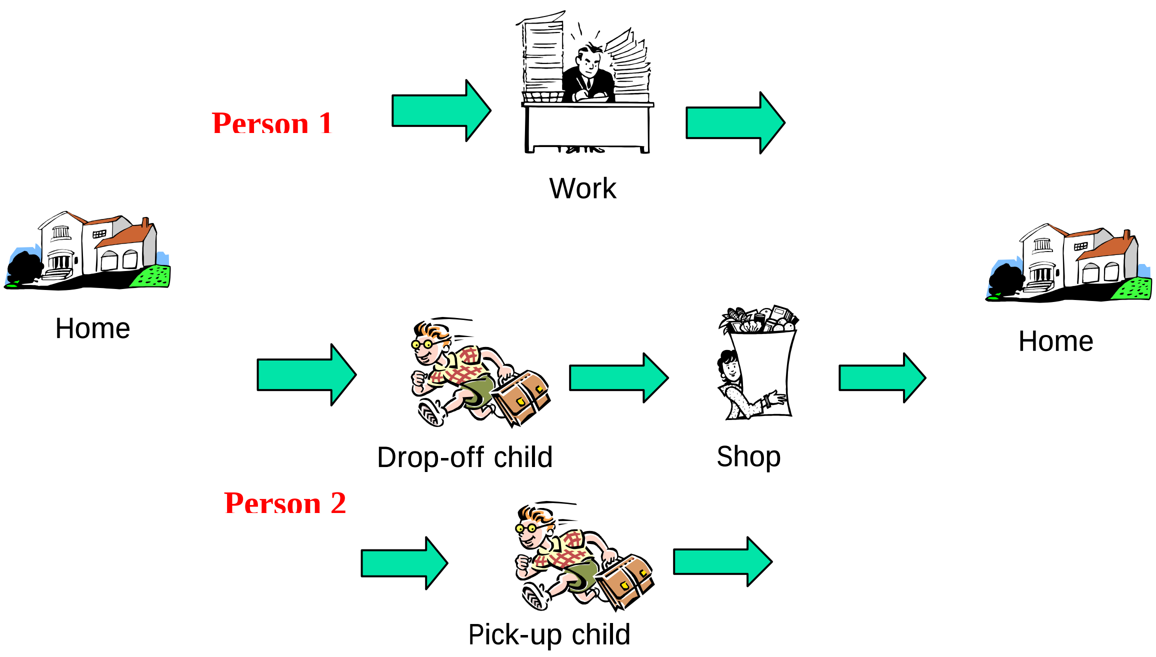


**Figure 5. Resoure sharing - linkages among trips of household members**

The duration and timing of trips are also important factors that can play a crucial role in the effects of a policy action. These factors are not considered explicitly by the trip-based approach in which time is simply represented as the ‘cost’ of making a trip. Take the example of a worker who typically leaves work at 5:00PM, drives to a grocery 15 minutes away, spends about 25 minutes shopping, and then gets back home by 6:00PM. An early release from work strategy designed by the employer might be expected to get the person off the road and back home by 5:00PM, before the peak hour as seen in Figure 6. But the individual, now released from work by 4:00PM and finding more time on his hands than usual, might decide to drive a longer distance to a preferred grocery where he spends more time shopping (70 minutes as against 25 minutes) and eventually returns home only at 6:00PM. So not only is the policy ineffective in keeping the person off the road during the peak hour, but also the longer time spent at the grocery has definite air quality implications.

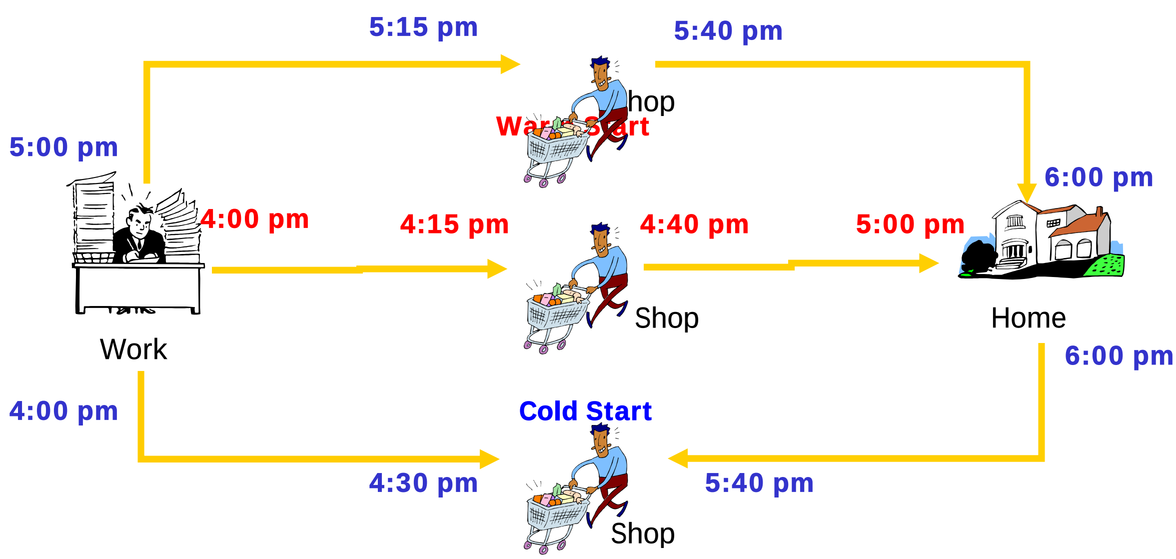


**Figure 6. Duration and timing of activities and trips**

To summarize, the trip-based approach ignores the linkages among trips over space, time and among different persons within a household. The key to these linkages is the activity participation behavior. As a result the activity-based approach to demand analysis has gained popularity and shown rapid development in the last few decades.

## 1.2 ACTIVITY-BASED APPROACH

The activity-based approach to travel demand analysis views travel as a derived demand; derived from the need to pursue activities distributed in space (see Jones et al., 1990 or Axhausen and Gärling, 1992). The approach adopts a holistic framework that recognizes the complex interactions between activity and travel behavior. The conceptual appeal of this approach originates from the realization that the need and desire to participate in activities is more basic than the travel that some of these participations may entail. By placing primary emphasis on activity participation and focusing on sequences or patterns of activity behavior (using the whole day or longer periods of time as the unit of analysis), such an approach can address congestion-management issues through an examination of how people modify their activity participations (for example, will individuals substitute more out-of-home activities for in-home activities in the evening if they arrived early from work due to a work-schedule change?).

The shift to an activity-based paradigm has also received impetus because of the increased information demands placed on travel models by the 1990 Clean Air Act Amendments (CAAAs). These amendments require the inclusion of transportation control measures (TCMs) in transportation improvement programs for MPOs in heavily polluted non-attainment areas and, by state law, for all non-attainment areas in California. Some TCMs, such as high occupancy vehicle (HOV) lanes and transit extensions, can be represented within the existing modeling framework; however, non-capital improvement measures such as ridesharing incentives, congestion pricing, and employer-based demand management schemes cannot be so readily represented (Deakin et al., 1993). The ability to model both individual activity behavior and interpersonal linkages between individuals, a core element of activity modeling, is required for the analysis of such TCM proposals. The CAAAs also require travel demand models to provide (for the purpose of forecasting mobile emission levels) link flows at a high level of resolution along the time dimension (for example, every 30 minutes or an hour as opposed to peak-period and off-peak period link flows) and also to provide the number of new vehicle trips (i.e., cold starts) which begin during each time period. Because of the simplistic, “individual-trip” focus of the trip-based models; they are not well-equipped to respond to these new requirements (see report by Cambridge Systematics, Inc., 1994). Since the activity-based approach adopts a richer, more holistic approach with detailed representation of the temporal dimension, it is better suited to respond to the new requirements.

Activity-based travel analysis has seen considerable progress in recent years. Several studies have focused extensively on the participation of individuals in single activity episodes, and on one or more accompanying characteristics of the episode such as duration, location, or the window of time in which the episode occurs. The effect of household interdependencies on individual activity choice is represented in these models in the form of simple measures such as presence of working spouse, number of adults, and household structure. Researchers have also made significant attempts to broaden the scope of earlier studies to examine activity episode patterns; that is, multiple activity episodes and their sequence over a particular time-span, typically a day. Some of these studies focus only on activity episode scheduling and consider the generation of activity episodes and their attributes as exogenous inputs. Other studies analyze both activity episode generation and scheduling, yielding more comprehensive activity-travel models. Such comprehensive models can potentially replace the conventional trip-based travel demand models (see Guo and Bhat, 2001, for a detailed review of the state-of-the-art in activity-based research).

Our research at the University of Texas at Austin aims to advance the state-of-the-art in daily activity-travel modeling. It represents one of the first attempts to comprehensively model the activity-travel patterns of workers as well as non-workers in a household. As part of this research, a simulation software called the "Comprehensive Econometric Micro-simulator for Daily Activity-travel Patterns" (CEMDAP) is being developed. As the name suggests, CEMDAP is a software implementation of a system of econometric models that represent the decision-making behavior of individuals. The software takes as input various land-use, socio-demographic, activity system, and transportation level-of-service attributes and provides as output the complete daily activity-travel patterns for each individual in the household.

This guidebook presents the activity-based approach to travel demand modeling using CEMDAP. The rest of this guidebook is organized as follows. Section 2 presents a representation framework for the activity-travel patterns of workers and non-workers, in the process identifying the various attributes that need to be modeled. Section 3 discusses the data needs for the analysis and application of activity-based model systems. Section 4 presents the modeling framework implemented within CEMDAP, and section 5 concludes the document.

## 2. What characterizes the daily activity-travel pattern of an individual?

Individuals make choices about different activities to be pursued during a day. Travel may be required to participate in these activities. The sequence of activities and travel that a person undertakes is defined as the individual's activity-travel pattern for the day. The objective of this section is to completely characterize the daily activity-travel patterns of individuals.

The activity-travel pattern of an individual is characterized based on whether she/he participates in an out-of-home mandatory (work/school) activity on the given day. The activity pattern of workers rests on the regularity and the fixity of the work activity. No such obvious fixity is present in the case of non-workers (retired people and homemakers). Recognizing this critical difference, representations are developed separately for workers and non-workers. The activity-travel patterns of students are characterized by the regularity of the school activity, analogous to the fixity of the work activity of the workers. The activity-travel patterns of students can, therefore, be represented by a framework similar to that of workers and hereafter the term 'worker' refers also to the school-goers. For both the worker and non-worker representations, we consider 3 a.m. as the beginning of the day and assume that the individual is at home during this time. The following discussion of activity-travel representations for workers and non-workers is drawn from earlier works by Bhat and Singh (2000) and Bhat and Misra (2000).

## 2.1 ACTIVITY-TRAVEL PATTERNS OF WORKERS

The daily pattern of workers is characterized by five different sub patterns: a) The pattern before the work commute (referred to as Before-Work or BW pattern), which represents the activity-travel undertaken before leaving home to work; b) The Home-Work commute pattern (referred to as HW pattern), which represents the activity-travel pursued during the home-to-work commute; c) The work-based pattern (referred to as WB pattern), which includes all activity and travel undertaken from work; d) The Work-Home commute pattern (referred to as WH pattern, which represents the activity-travel pursued during the work-to-home commute; and e) The post home arrival pattern (referred to as After-Work or AW pattern), which comprises the activity and travel behavior of individuals after arriving home at the end of the work-to-home commute. The home-to-work and work-to-home commute patterns are closely linked since the travel mode for both these commutes will, in general, be the same, or at the very least dependent. Within each of the BW, WB and AW patterns, there might be several tours. A tour is a circuit that begins and ends at home for the BW and AW patterns and is a circuit that begins and ends at work for WB pattern. Further, each tour within the BW, WB and AW patterns may comprise several activity stops. Similarly, the HW and WH commute patterns may also comprise several activity stops. Figure 7 provides a diagrammatic representation of the worker activity-travel pattern in terms of the overall pattern, the component tours and stops.

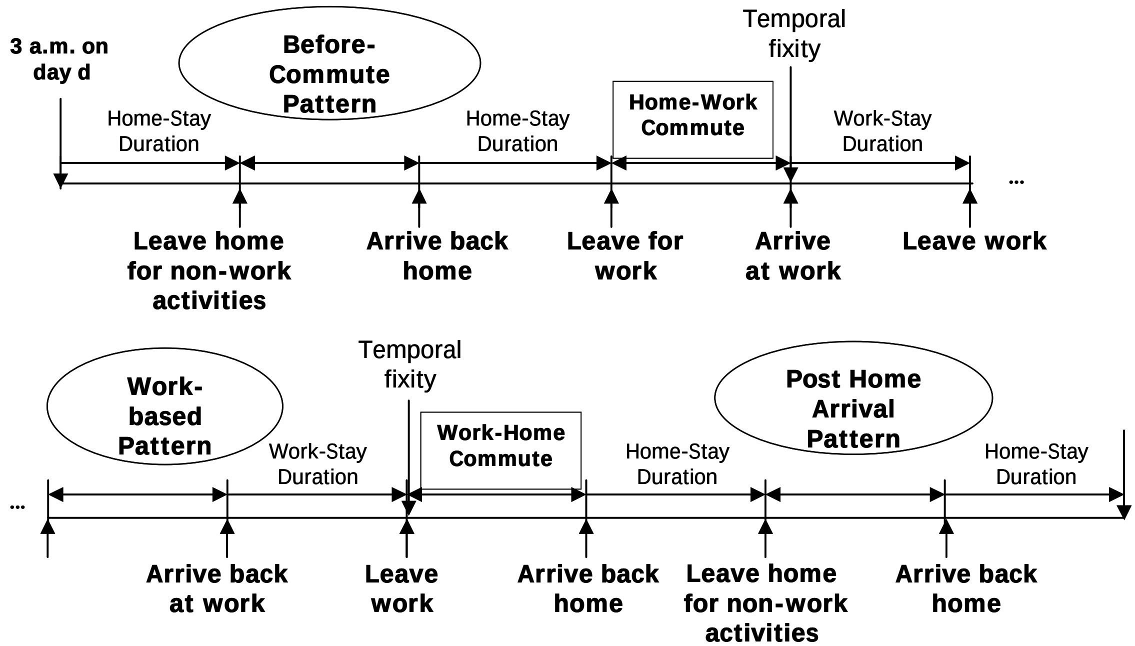


**Figure 7. Diagrammatic representation of worker activity-travel pattern**

The characterization of the complete workday activity-travel pattern is accomplished by identifying a number of different attributes within the representation discussed above. These attributes may be classified based on the level of representation they are associated with: that is, whether they are associated with a pattern, a tour, or a stop. Pattern-level attributes include the number of tours for the BW, WB and AW patterns, and the home-stay duration before the HW commute pattern. Tour-level attributes include the travel mode, number of stops, and home-stay duration before each tour in the BW and AW patterns, work-stay duration before each tour in the WB pattern, and the sequence of tours in each pattern. Stop-level attributes include activity type, travel time from previous stop, location of stop, activity duration, and the sequence of the stop in the tour.

## 2.2 ACTIVITY-TRAVEL PATTERNS OF NON-WORKERS

In the case of non-workers, the activity-travel pattern is considered as a set of out-of-home activity episodes (or stops) of different types interspersed with in-home activity stays. The chain of stops between two in-home activity episodes is referred to as a tour. The pattern is represented diagrammatically in Figure 8. A non-worker's daily activity-travel pattern is characterized again by attributes associated with the entire daily pattern, a tour in the day, and a stop. Pattern-level attributes include whether or not the individual makes any stops during the day, the number of stops of each activity type if the individual leaves home during the day, and the sequencing of all episodes (both stops and in-home episodes). The only tour-level attribute is the travel mode for the tour. Stop-level attributes include the activity duration, travel time to stop from previous episode (except for the first home-stay episode), and the location of out-of-home episodes (i.e., stops).

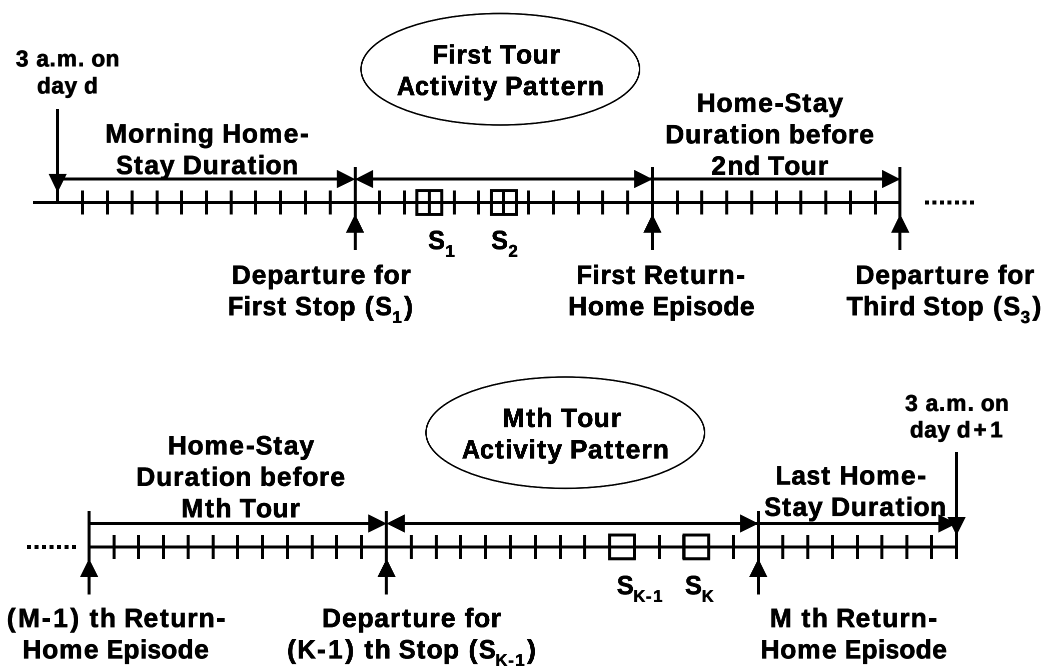


**Figure 8. Diagrammatic representation of the activity-travel pattern of non-workers**

The modeling of the activity-travel pattern of individuals entails the determination of each of the attributes that characterize the three-level representation structure described above. Due to the large number of attributes and the large number of possible choice alternatives for each attribute, the joint modeling of all these attributes is infeasible. Consequently, a modeling framework that is feasible to implement from a practical standpoint is required. The framework adopted in CEMDAP is described in section 4.

# 3. Data needs for activity-based travel analysis

The previous section identifies the various attributes that characterize the activity-travel patterns of individuals. Before we can take a look at the framework developed for modeling all these attributes, it is appropriate to think about the data needs for such an endeavor.

## 3.1 DATA REQUIREMENTS FOR ANALYSIS

The data required for analysis and estimation of activity-based travel demand models can be elicited from conventional travel surveys. These surveys contain a lot of information about the sequence of trips, time of day etc., which is not used in the four-step process. However, in order to exploit the activity-based approach to the fullest extent time-use survey data must be used. A time-use survey entails the collection of data regarding all activities (in-home and out-of-home) pursued by individuals over the course of a day (or multiple days). Travel constitutes the medium for transporting oneself between spatially dis-located activity participations. The examination of both in-home and out-of-home activities facilitates an understanding of how individuals substitute out-of-home activities for in-home activities (or vice-versa) in response to changing travel conditions. This, in turn, translates to an understanding of when trips are generated or suppressed. As part of the time-use survey detailed household and individual socio-demographic information must also be collected due to the disaggregate nature of the activity-based approach.

It is important to note that administrating time-use surveys is similar to administrating household travel surveys, except for the collection of in-home as well as out-of-home activities. The information elicited from respondents is a little more extensive in time-use surveys compared to travel surveys, but experience suggests that the respondent burden or response rates are not significantly different between time-use and travel surveys (see Lawton and Pas, 1996, for an extensive discussion). On the other hand, such intensive scrutiny of data helps identify data inconsistencies which might go unchecked in the trip-based approach (for example, there might be "gaps" in an individual's travel diary because of non-reporting of several trips; these will be identified during data preparation for activity analysis, but may not be identified in the trip-based approach since it highlights individual trips and not the sequence between trips and activities).

In addition to the survey data, the activity-based approach requires the usual land-use and level-of-service attributes for the study-area. These together with the socio-demographic data serve as exogenous variables to the econometric model system.

## 3.1 DATA REQUIREMENTS FOR APPLICATION

As opposed to the trip-based approach which requires aggregate zonal-level data, the application of a micro-simulation based activity-travel modeling system (such as CEMDAP) will require household and individual socio-demographic data for the entire population of the study area. Population data of this magnitude and level of disaggregation can be assembled in many ways. One such method is the synthetic population generation technique. Bhat et al. (2003b) present the application of this method to generating a synthetic population for the Dallas-Fort Worth metropolitan area for the year 2000. In addition, the usual forecast year land-use and level-of-service attributes will also be required.

## 4. Framework for an activity-based modeling system

Computational process models (CPMs) and econometric models are the two most common approaches adopted in the development of activity-based modeling systems. Guo and Bhat (2001) discuss in detail several operational model systems and their mechanisms. The model system embedded in CEMDAP adopts the econometric modeling approach. The econometric modeling approach involves using systems of equations to capture relationships among macroscopic indicators of activity and travel, and to predict the probability of decision outcomes. These models explore how activity and travel patterns are related to land use and socio-demographic characteristics of the traveler. The main criticism of the econometric approach is that it does not explicitly model the behavioral mechanisms underlying activity engagement and travel. This limits the richness of the behavior theories that can be incorporated into the model system (refer Kitamura, 1996)). Nevertheless, the family of econometric models - ranging from discrete choice models, hazard duration models and limited-dependent variable models - remains a powerful approach to activity-travel analysis. Its strength lies in allowing the examination of alternative hypotheses about the causal relationships among behavioral indicator.

The overall framework (see Figure 9) adopted in CEMDAP comprises of two major components: the generation-allocation model system and the scheduling model system. The purpose of the generation-allocation model system is to identify the decisions of individuals to participate in activities, as motivated by both individual and household needs. The scheduling system uses these decisions as input to model the complete activity-travel pattern. Based on the distinction made between the representations of worker and non-worker patterns, separate scheduling model systems are proposed for workers and non-workers. Each of these model systems is described in greater detail in the following subsections. Appendix A lists all the model components of each of these model systems along with their econometric structures as prescribed in CEMDAP. Also listed is a simple model structure that is supported for each model component in the absence of an estimated model of the prescribed type. Refer Bhat et al. (2002, 2003a) for further details on the conceptual and analysis frameworks.

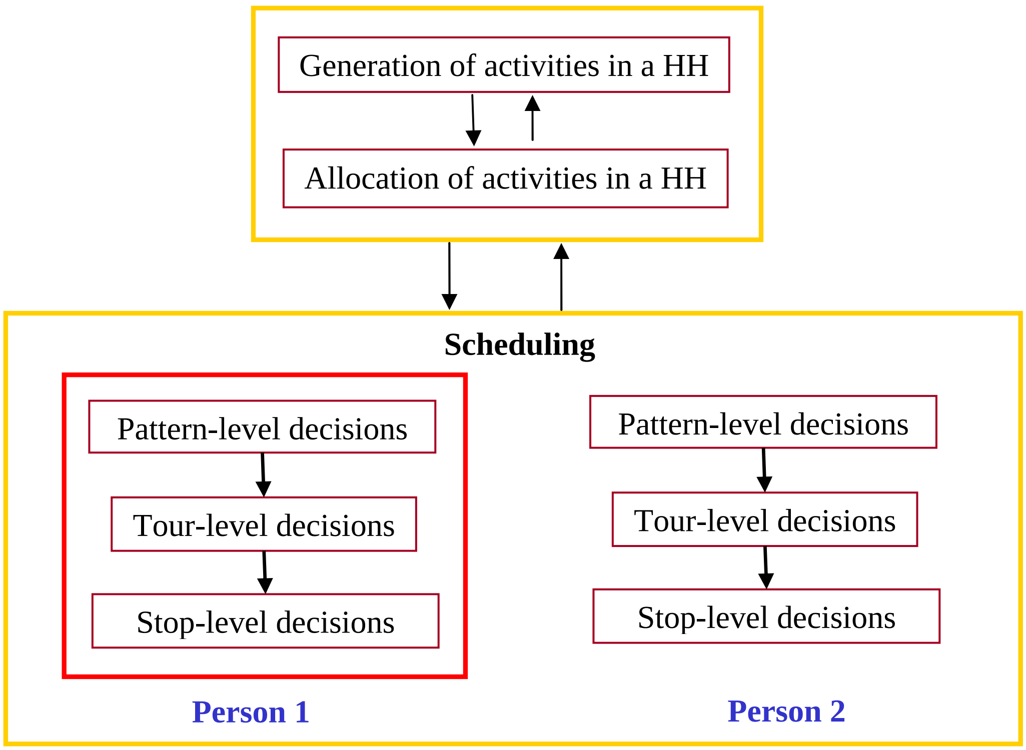


**Figure 9. Overall modeling framework**

### 4.1 THE GENERATION-ALLOCATION MODEL SYSTEM

The generation-allocation system models the decisions of the household adults to participate in activities of different types during the day. As shown in Figure 10, the first set of models in this system focus on the individual's decision to participate in mandatory activities such as work or school. For each employed adult in the household, the decision to go to work is first determined.  If the person decides to work (out of home) on the given day, she or he is thereafter classified as a worker and the work-based duration and work start-times are then determined.  The decisions of students are similarly determined.  If a student decides to travel to school, she or he is treated as a worker for the remainder of the modeling process.

The household's decision to participate in shopping, personal business and social/recreational activities is modeled next.  This activity-generation group of models captures the trade-offs made by a household in choosing to participate in different types of activities for the day.  If the household has only a single adult, activity allocation is trivial.  In the case of multi-adult households, the allocation of activities to individuals in the household is modeled by the activity-allocation models, one for each activity type.  The last component in the generation-allocation model system is the 'other' activity participation model, which determines the individual's decision to participate in activities such as eating out or pick-up/drop-off.  This model is applied separately to each adult in the household.

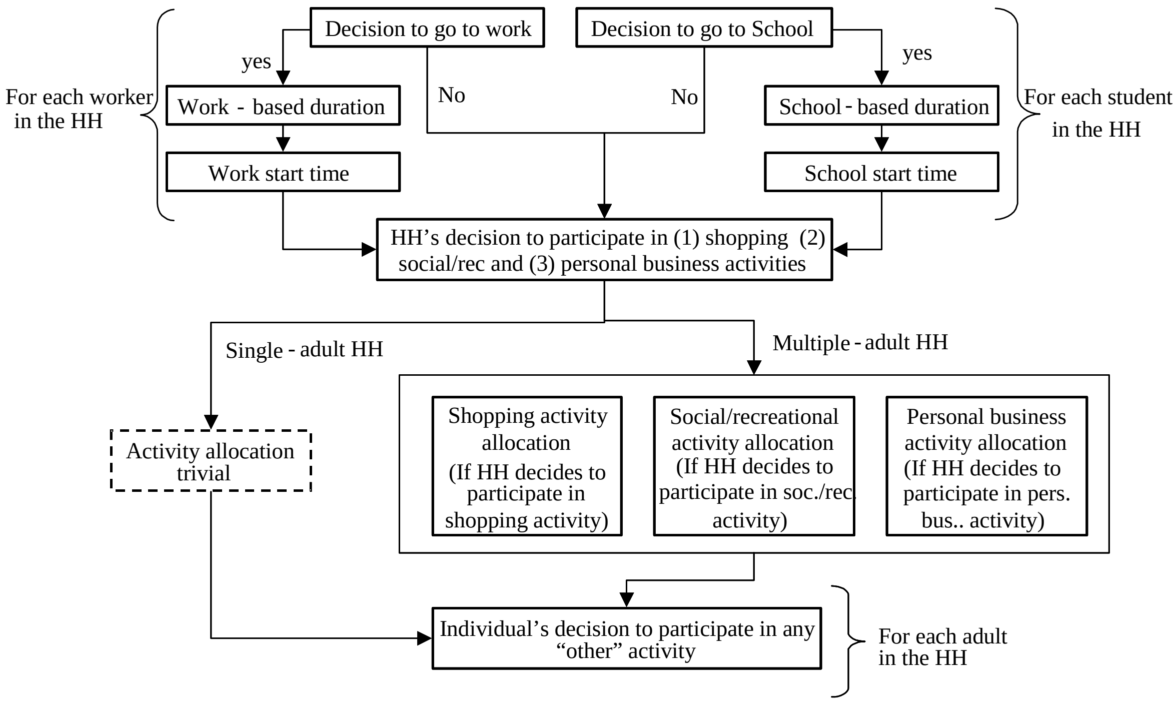


**Figure 10. The generation-allocation model system**

The application of the generation-allocation model system to a household will yield as output the decision of each household adult to participate in different activities such as work (only for employed persons), school (only for students), shopping, social/recreational activities, personal business and 'other' activities. In addition, the work/school start- and end-times will also be determined.

## 4.2 THE SCHEDULING MODEL SYSTEM FOR WORKERS

The scheduling model system for workers can be subdivided into three sequential model systems: the pattern-level, the tour-level and the stop-level model systems. Each of these sub-systems corresponds to one level in the daily activity-travel representation framework.

The pattern-level sub-system for workers is presented in Figure 11. The attributes of the WH commute are determined first. A model for number of stops is applied only if the worker has decided to participate in activities other than work during the day. Next, the HW commute is characterized. If work is the worker's only activity for the day, the characterization of the worker's activity-travel pattern for the day is complete at this point. However, if the worker has also decided to participate in other activities, the final pattern-level model is applied to predict the worker's decision to undertake a tour during one or more of BW, WB and AW patterns.

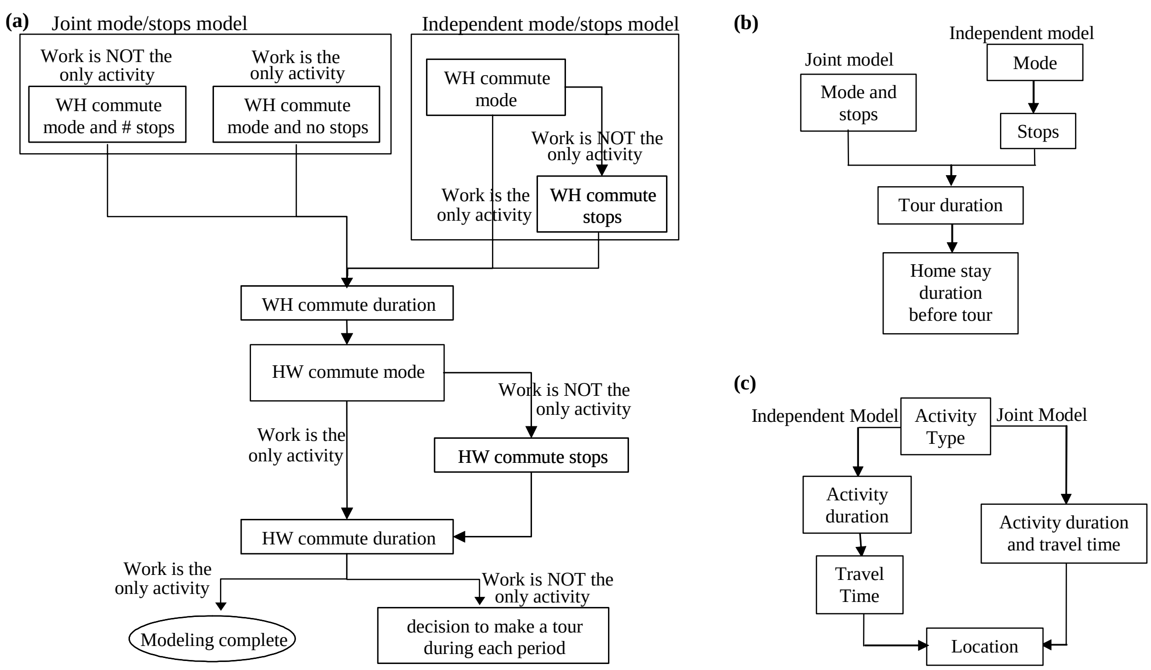


**Figure 11. The scheduling model system for workers: (a) pattern-level sub-system, (b) tour-level sub-system, and (c) stop-level sub-system**

The modeling of the BW, WB and AW tours, if any, involves repeated applications of the tour-level model system shown in Figure 11(b). The tour mode and number of stops may be determined simultaneously using a joint model or sequentially using independent models. Analogous to the modeling of tour-level attributes, stop characteristics are determined by the stop-level model system (see Figure 11(c)), which is applied for stops made during the WH and HW commutes first, followed by stops made as a part of any other tour (BW/WB/AW). Within any tour or commute, the characteristics of stops are determined sequentially from the first to the last stop.

## 4.2 THE SCHEDULING MODEL SYSTEM FOR NON-WORKERS

Analogous to the scheduling model system for workers, the scheduling model system for non-workers can also be subdivided into three sequential sub-systems. If the non-worker did not decide to participate in any activity during the day, there are no scheduling decisions to be modeled, and the characterization of this person's activity-travel pattern is complete by noting that the person stays home all day. However, if the non-worker decided to participate in one or more activity types for the day, the total number of tours is determined. This is the only model in the pattern-level model system for non-workers. The tour-level model system, identical to that for the workers (Figure 11(b)), is then applied sequentially to determine the characteristics of each of the tours. Finally, the stop-level model system, again identical to that for the workers (Figure 11(c)), is applied sequentially to all the stops in each tour.

The conceptual framework presented above provides a "natural" way to visualize the activity-travel generation of individuals within a household context. The generation-allocation-scheduling approach captures inter-personal dependencies in terms of joint activity participation and the delegation of tasks among the members of a household. It also explicitly considers the sharing of autos in making trips.

## 5. Conclusion

The activity-based approach to travel demand analysis views travel as a derived demand; derived from the need to pursue activities distributed in space. A comprehensive activity-based travel demand modeling system, such as the one developed at the University of Texas at Austin (Comprehensive Econometric Micro-simulator for Daily Activity-travel Patterns or CEMDAP), recognizes explicitly the spatial, temporal and inter-personal constraints and inter-dependencies in activity and travel choices. It takes into account a detailed consideration of the timing and duration of activities and travel, and emphasizes the decision-making at the household level and the interactions among household members. By placing primary emphasis on activity participation and focusing on sequences or patterns of activity behavior (using the whole day or longer periods of time as the unit of analysis), such an approach can better understand travel behavior responses to shorter-term congestion management policies. Since the activity-based approach adopts a richer, more holistic approach with detailed representation of the temporal dimension, it is also better suited to respond to the new CAAAs requirements.

This guidebook presents the representation frameworks for the activity-travel patterns of workers and non-workers, in the process identifying the various attributes that need to be modeled. Following the representation frameworks is a brief discussion of the data needs for the analysis and application of activity-based model systems. Finally, the model system embedded in CEMDAP is described in detail. For more information on the software processes and mechanisms underlying CEMDAP, and software deployment procedures refer Bhat et al. (2003c).

# Appendix A. Components of Model System

The complete listing of the components of the model system embedded in CEMDAP is presented in the following tables. Also listed are the econometric structures prescribed in CEMDAP for the model components, and a simple model type supported in case estimated models of the prescribed type are not available.

**Components of the generation-allocation model system**

| Model Description | Prescribed Model Type | Simple Model Type |
|---|---|---|
| Decision to go to work | Binary logit | Constant only |
| Work-based duration | Hazard-duration[1] | Simple Probabilistic |
| Work start time | Hazard-duration[1] | Simple Probabilistic |
| Decision to go to school | Binary logit | Constant only |
| School-based duration | Linear-regression | Simple Probabilistic |
| School start time | Linear-regression | Simple Probabilistic |
| HH activity generation | Multinomial logit | Constants only |
| Shopping activity allocation | Binary logit | Constant only |
| Social/Recreational activity allocation | Binary logit | Constant only |
| Personal business activity allocation | Binary logit | Constant only |
| "Other" activity participation | Binary logit | Constant only |

[1] proportional hazard function with non-parametric baseline hazard and gamma heterogeneity

**Components of the scheduling model system for workers**

| Model Description | Prescribed Model Type | Simple Model Type |
|---|---|---|
| **The pattern-level model system** | | |
| WH commute mode | Multinomial logit | Constants only |
| WH commute stops | Ordered probit | Thresholds only |
| WH commute duration | Linear-regression | Simple Probabilistic |
| HW commute mode (WH Drive-Alone) | Binary logit | Constants only |
| HW commute mode (WH Drive-Alone/Shared-Ride) | Binary logit | Constants only |
| HW commute stops | Ordered probit | Thresholds only |
| HW commute duration | Linear-regression | Simple Probabilistic |
| Decision to make a tour in each period | Multinomial logit | Constants only |
| **The tour-level model system[1]** | | |
| Mode | Multinomial logit | Constants only |
| Stops | Ordered probit | Thresholds only |
| Tour duration | Linear-regression | Simple Probabilistic |
| Home-stay duration before tour | Linear-regression | Simple Probabilistic |

| The stop-level model system[2] | | |
|---|---|---|
| Activity type | Multinomial logit | Constants only |
| Activity duration | Linear-regression | Simple Probabilistic |
| Travel time | Linear-regression | Simple Probabilistic |
| Location | Spatial location choice | Multinomial logit |

[1] Separate models for each of the BW, WB and AW tours

[2] Separate models for stops in each of WH and HW commutes and BW, WB, and AW tours

## Components of the scheduling model system for non-workers

| Model Description | Prescribed Model Type | Simple Model Type |
|---|---|---|
| **The pattern-level model system** | | |
| Number of tours | Ordered probit | Thresholds only |
| **The tour-level model system[1]** | | |
| Mode | Multinomial logit | Constants only |
| Stops | Ordered probit | Ordered probit |
| Tour duration | Linear-regression | Simple Probabilistic |
| Home-stay duration before tour | Linear-regression | Simple Probabilistic |
| **The stop-level model system[2]** | | |
| Activity type | Multinomial logit | Constants only |
| Activity duration | Linear-regression | Simple Probabilistic |
| Travel time | Linear-regression | Simple Probabilistic |
| Location | Spatial location choice | Multinomial logit |

[1] Separate models for tours 1 2 3 and 4

[2] Separate models for stops in each of tours 1 2 3 and 4

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