Comprehensive Econometric Microsimulator for Daily Activity-Travel Patterns

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The Comprehensive Econometric Microsimulator for Daily Activity-Travel Patterns (CEMDAP) is a microsimulation implementation of an activity-travel modeling system. Given as input various land use, sociodemographic, activity system, and transportation level-of-service attributes, the system provides as output the complete daily activity-travel patterns for each individual in each household of a population. The underlying econometric modeling framework and the software development experience associated with CEMDAP are described. The steps involved in applying CEMDAP to predict activity-travel patterns and to perform policy analysis are also presented. Empirical results obtained from applying the software to the Dallas–Fort Worth area demonstrate that CEMDAP provides a means of analyzing policy impacts in ways that are generally infeasible with the conventional four-stage approach.

The activity-based approach to travel demand analysis views travel as a demand derived from the need to pursue activities distributed in space (*1, 2*). The approach adopts a holistic framework that recognizes the complex interactions in activity and travel behavior. The conceptual appeal of this approach originates from the realization that the need and desire to participate in activities are more basic than the travel that some of these participations may entail. Because of the emphasis on activity behavior patterns, such an approach can address congestion management issues through an examination of how people modify their activity participation (for example, whether individuals will substitute more out-of-home activities for in-home activities in the evening if they arrive home early from work because of a work-schedule change).

Activity-based travel analysis has seen considerable progress in the past couple of decades and has led to the development of several comprehensive activity-travel models. These models typically fall into one of two categories: econometric models and computational process models. The econometric modeling approach involves using systems of equations to capture relationships among activity and travel attributes and to predict the probability of decision outcomes. The strength of this approach lies in allowing the examination of alternative hypotheses regarding the causal relationships among activity-travel patterns, land use, and sociodemographic characteristics of individuals. A computational process model is, in contrast, a computer program implementation of a production system model, which is a set of rules in the form of condition-action (if-then) pairs that specify how a task is solved (*3*). The approach focuses on the process of decision making and captures schedule constraints explicitly. Hence, computational process models potentially offer more flexibility than econometric models do in representing the complexity of travel decision making.

The desire to move activity-travel models—both the econometric models and the computational process models—into operational practice has stoked the interest in microsimulation, a process through which the choices of an individual are simulated dynamically on the basis of the underlying models. Activity-travel microsimulation systems provide a means of forecasting the impacts of a given policy at the disaggregate level so that detailed analysis of model results can be performed in ways that are generally infeasible with the conventional four-stage approach (*4*). To date, partial and fully operational activity-based microsimulation systems include the Microanalytic Integrated Demographic Accounting System (MIDAS) (*5*), the Activity-Mobility Simulator (AMOS) (*6*), the Prism Constrained Activity-Travel Simulator (PCATS) (*7*), SIMAP (*8*), Albatross (*9*), TASHA (*10*), Florida's Activity Mobility Simulator (FAMOS), and other systems developed and applied to varying degrees in Portland, Oregon; San Francisco, California; and New York City (*4, 11*). A review of these activity-travel microsimulation systems is available at the website www.ce.utexas.edu/prof/bhat/REPORTS/4080_1.pdf.

The development of the Comprehensive Econometric Microsimulator for Daily Activity-Travel Patterns (CEMDAP) at the University of Texas at Austin is described here. As the name suggests, CEMDAP is a software implementation of a system of econometric models that represent the decision-making behavior of individuals. The system differs from its predecessors in that it is one of the first to comprehensively simulate the activity-travel patterns of workers as well as nonworkers along a continuous time frame. Given various land use, sociodemographic, activity-system, and transportation level-of-service (LOS) attributes as input, the system provides as output the complete daily activity-travel pattern for each individual in each household of an urban population. The sociodemographic inputs required by the software include household and person-level attributes for the entire population of the study area, which can be obtained by using methods such as synthetic population generation; such a procedure has already been undertaken to generate the entire population for the Dallas–Fort Worth (DFW) area, in Texas. From a software engineering point of view, CEMDAP represents a generic

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library of object-oriented codes that supports rapid implementation of econometric modeling systems for activity-travel pattern generation.

In the next section the representation and modeling framework underlying CEMDAP is presented. Software development issues, including the development paradigm, system architecture, simulation sequence, simulation mechanism, and user interface, are discussed, followed by a demonstration of the application of the software for forecasting and policy analysis. Directions for future work are outlined in the final section.

The design and development of CEMDAP is an ongoing project. The research team is working on enhancing the microsimulator in many ways. The prototype Version 0.3 of the software is described here. The reader is referred to research reports and other periodically updated documentation provided online (www.ce.utexas.edu/prof/bhat/REPORTS) for descriptions of the system at any time.

REPRESENTATION AND MODELING FRAMEWORK

Individuals make choices about the activities to pursue during the day, some of which may involve travel. The sequence of activities and travel that a person undertakes is defined as the individual's activity-travel pattern for the day.

The conceptual modeling framework embedded within CEMDAP in its current form is designed only to simulate the activity-travel patterns of adults (aged 16 years and over). Extension of CEMDAP to include the modeling of the activity-travel patterns of children is an area of ongoing research.

The activity-travel pattern of an adult individual is characterized on the basis of whether she or he participates in an out-of-home mandatory work activity on the given day. This distinction between worker and nonworker patterns is discussed further in the next subsection. The activity-travel patterns of adult students are characterized by the regularity of the school activity, analogous to the fixity of the work activity for workers. The activity-travel patterns of students are therefore represented by a framework similar to that of workers.

In CEMDAP, an activity-travel pattern is represented by a three-level structure: stop, tour, and pattern. A stop represents an out-of-home activity episode in which an individual participates. It is characterized by the type of activity undertaken, the duration of the stop, the travel time to the stop, and the stop location. A chain of stops made as a part of the same home-to-home, work-to-work, home-to-work (HW), or work-to-home (WH) sojourn constitutes a tour. The HW and the WH sojourns are also respectively referred to as the WH and HW commutes. A tour is described by the mode used, duration of the tour, number of stops, and the home-stay duration immediately before the tour. A pattern is then a sequence of tours undertaken during a day. The representation pattern used in CEMDAP for worker and nonworker patterns is discussed in the next subsection.

The modeling of the activity-travel patterns of individuals entails the determination of each of the attributes that characterize the three-level representation structure. Because of 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 modeling framework adopted in CEMDAP is described in the section on overall modeling framework [a more detailed description may be found elsewhere (*12*)].

Representation of Worker and Nonworker Patterns

The need to participate in out-of-home mandatory activities, such as work or school, imposes constraints on participation in other types of activities. In particular, for individuals who work away from home or attend school, the commute between home and work or school constitutes an important part of their daily activity-travel pattern. Also, the specific period of time for which a worker (or student) needs to be at work (or school) has a significant influence on her or his decisions to pursue and schedule other activities. This observation has led to the use of the work (or school) activity as a peg to characterize the activity-travel pattern of workers (or students) (*13–15*).

In CEMDAP, the work start and end times act as temporal pegs on which the worker's complete activity-travel pattern rests (for ease in presentation, the term "work" will be used to refer to both work and school and the term "worker" to refer to both employed persons who travel to work and students who travel to school). These pegs, along with the commute durations, determine the departure time to work and the arrival time at home from work. Thus, a worker's day may be partitioned into five periods: (*a*) the before-work (BW) period (from 3:00 a.m. until departure to work), (*b*) the HW commute (from HW departure time to work start time), (*c*) the work-based (WB) period (from work start time to work end time), (*d*) the work-to-home (WH) commute (from work end time to the arrival time at home), and (*e*) the after-work (AW) period (from the arrival time at home from work to 3:00 a.m. of the following day). The pattern of a worker is therefore characterized by the commutes and the tours a worker undertakes during each of the BW, WB, and AW periods. Figure 1*a* provides a diagrammatic representation of a worker's activity-travel pattern using the three-level structure, where S_1, S_2, S_3, and so on, refer to stops made by the worker during the day.

Unlike the case of workers, there are no regular temporal fixities in the overall travel patterns of nonworkers. Hence the nonworkers' daily activity-travel pattern is simply characterized by a sequence of home-based tours. Figure 1*b* shows the representation of a nonworker's complete activity-travel pattern in terms of tours and stops.

Overall Modeling Framework

The overall framework adopted in CEMDAP includes 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 of individuals. On the basis of the distinction made between the representations of worker and nonworker patterns, separate scheduling model systems are proposed for workers and nonworkers. Each of these model systems is described in greater detail in the following subsections.

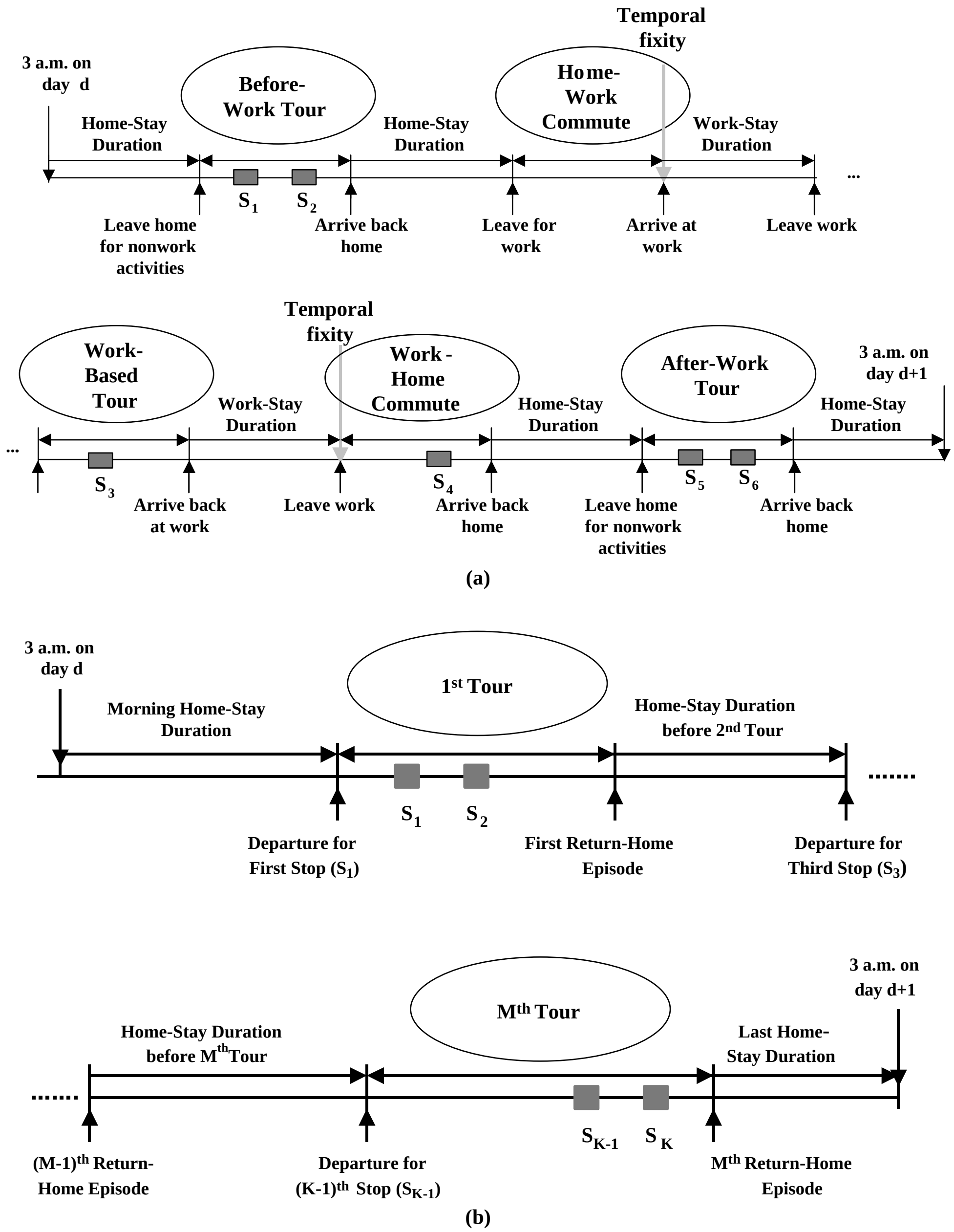

FIGURE 1 Representations for daily activity-travel patterns: (*a*) for workers and (*b*) for nonworkers.

Generation-Allocation Model System

The generation-allocation system models the decisions of household adults to participate in activities of different types during the day. As shown in Figure 2, the first set of models in this system focus on the individual's decision to participate in mandatory activities such as work or school. The employment status of the household adults (employed, studying, or not employed) is taken as an input by CEMDAP. For each employed adult in the household, the decision to go to work is first determined. If the person decides to travel to work on the given day, she or he is classified as a worker and the work-based duration and work start times are determined. The decisions of students are similarly determined. If a student decides to travel to school, she or he is treated as a worker in the modeling process. All the remaining household members who are not classified as workers are designated as nonworkers.

The household's decision to undertake shopping is modeled next. Shopping is often undertaken to serve the maintenance needs of the household and is therefore modeled as a decision of the household as a whole rather than that of any particular individual. The allocation of the shopping responsibility to one or more individuals in multiadult households is then modeled (in terms of the decisions of

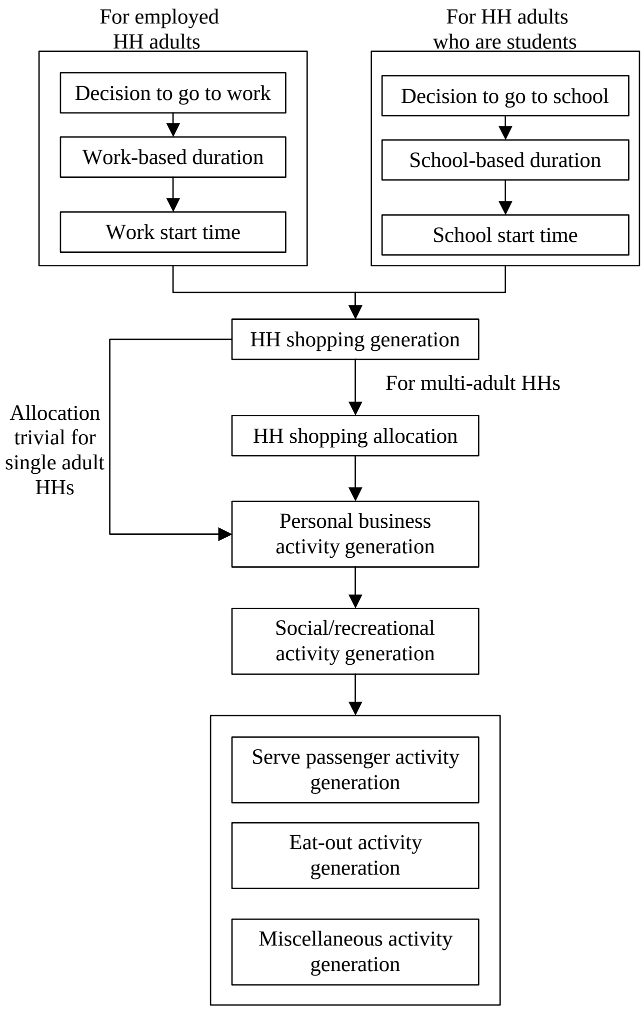

FIGURE 2 Generation-allocation model system (HH = household).

each household member to undertake the generated activity). It should be noted that the activity allocation is trivial in single-adult households. Further, it is also possible that household members decide to undertake activities jointly. The current version of CEMDAP does not support joint activity participation. However, this is an important area of current research.

The next set of five models determines the decisions of individuals to undertake activities for personal business, social-recreation, serve-passenger, eat-out, and other miscellaneous reasons. Another important area of future work is to develop means to explicitly accommodate the spatial and temporal constraints imposed by the decision to undertake serve-passenger activities, especially in the context of pickup and drop-off of children at school.

In summary, the generation-allocation model system determines the decision of the household adults to undertake various activities during the day. Decisions about mandatory activities (work and school) are assumed to be made first and constrain all other activity participation decisions. Decisions about household maintenance activities (shopping) are then assumed to be made, followed by the decisions about discretionary and flexible activity purposes (the labels "activity purposes" and "activity types" are used interchangeably in this paper).

Scheduling Model System for Workers

The scheduling model system for workers is partitioned into three sequential model systems: the pattern-level, the tour-level and the stop-level model systems. Each of these systems corresponds to one level in the daily activity-travel representation framework, as discussed earlier.

The pattern-level system for workers is presented in Figure 3*a*. The attributes of the WH commute are determined first on the basis of the demographics, land use, transportation system characteristics, and the decision outputs of the generation-allocation model system. The attributes of the WH commute include the travel mode, number of stops, and commute duration. It should be noted that the number of commute stops is modeled only for those workers who have decided to undertake nonwork activities (determined as part of the generation-allocation model system; the number of stops for persons not undertaking any nonwork activities is necessarily zero).

Next, the HW commute is characterized in terms of the travel mode, number of stops, and commute duration. These attributes for the HW commute are dependent on, among other things, the attributes of the WH commute. 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 [see lower left-hand side of Figure 3*a*]. However, if the worker has decided to participate in other activity purposes also, the number of tours to be undertaken during each of the AW, WB, and BW periods is modeled [a detailed discussion of, and motivation for, the overall structure used here may be found elsewhere (*15*)]. On the basis of the work schedule (determined in the generation-allocation model system) and the commute durations (determined in the pattern-level model system) the time of departure from home to work and time of arrival back at home from work are computed. This determination in turn provides the time available for undertaking tours during each of the AW, WB, and BW periods. The available time so computed is used in the determination of the number of tours made during each period, thereby capturing the effect of temporal constraints.

The tour-level model system (Figure 3*b*) predicts the tour-level attributes for each of the tours in the BW, WB, and AW periods (if any such tours are predicted in the pattern-level model system). The tours in each of these periods are modeled independently on the basis of the empirical finding by Bhat and Singh (*15*) that out-of-home activities participated in during the BW, WB, and AW periods are independent of one another. If multiple tours are made during any period, these are modeled sequentially from the first to the last tour within the period. Within the tour-level model system, the tour mode and number of stops are first modeled. The tour duration is modeled next, followed by the duration of home stay (work stay in the case of WB tours) before the tour. Measures of the time available for participation in activities during each of the BW, WB, and AW periods are used as explanatory variables to capture time constraints in the tour duration and home-stay duration models.

Analogous to the modeling of tour-level attributes, stop characteristics (activity purpose, stop duration, travel time to stop, and stop location) are determined by the stop-level model system (see Figure 3*c*). For each stop, a discrete choice model is used to determine activity type, followed by regression models for activity stop duration and travel time to stop from previous episode. Finally, a location choice model is applied to determine stop location. In the stop-level

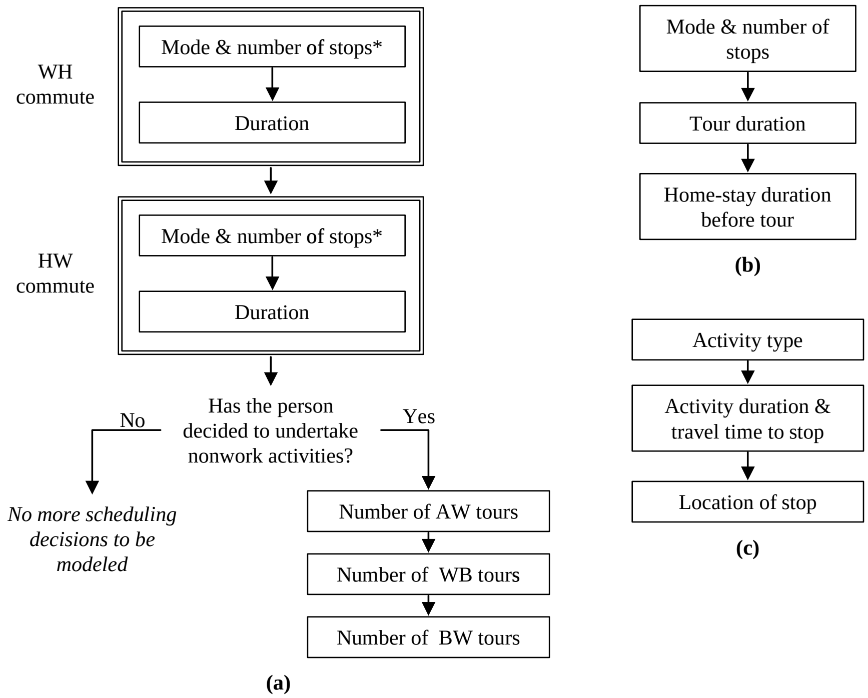

FIGURE 3 Scheduling model system: (*a*) pattern level for workers, (*b*) tour level for workers and nonworkers, and (*c*) stop level for workers and nonworkers. (* indicates that number of stops is determined only if the worker has decided to undertake nonwork activities.)

model system, the stops made during the WH and HW commutes are modeled first, followed by stops made as a part of any other tour. Within the commutes or tours, the characteristics of stops are determined sequentially from the first to the last stop (it should be noted that the number of stops in the commute or tour has already been determined). After the characteristics of the first stop are determined, the time available for a second stop in the commute or tour is computed on the basis of the difference between the overall tour duration or commute duration (predicted in the tour-level model system) and the travel time and stop duration to the first stop. This available time is used as an explanatory variable for determining the characteristics of the second stop. This process is continued until the attributes of all stops in the commute or tour are obtained.

Scheduling Model System for Nonworkers

The scheduling model system for nonworkers is also partitioned into three sequential systems. If the nonworker does not participate in any activity purpose during the day (as determined in the generation-allocation system), there are no scheduling decisions to be modeled, and the characterization of this person's activity-travel pattern is completed by noting that the person stays home all day. However, if the nonworker participates in one or more activity types for the day, the total number of tours is determined in the pattern-level model system for nonworkers. Each of the tours is sequentially characterized from the first (or earliest) to the last tour using the tour-level model system (Figure 3*b*). The information on the number of tours to be undertaken (predicted by the pattern-level system) is used as an explanatory variable in determining the number of stops for each tour, thereby introducing linkages among the choices of the different tours. Again, analogous to the scheduling model system for workers, measures of available time are used as explanatory variables to capture time constraints. The duration of the first tour and the home-stay duration before it determine the available time for the second tour. The total time invested in the first and second tours and in the home stay before these tours determines the available time for the third tour, and so on. Within each tour, the stops are characterized sequentially using the stop-level model system (Figure 3*c*). The complete details of the many model components and mathematical formulations for the generation-allocation and scheduling system are available elsewhere (*16*).

SOFTWARE DEVELOPMENT

The primary goal of CEMDAP is to produce simulated activity-travel patterns based on the behavioral modeling system outlined in the previous section. As shown in Figure 4, the system starts with the aggregate demographics of the population for the forecast year. A synthetic population generator translates the aggregate demographics to a disaggregate population of households and individuals within the household. The analyst also needs to provide the transportation system attributes (level of service for different modes by time of day) and the land use patterns of the planning area (also referred to as the activity-environment characteristics) for the forecast year as input.

In addition, CEMDAP requires the user to specify or configure the structures or parameters for the underlying econometric models.

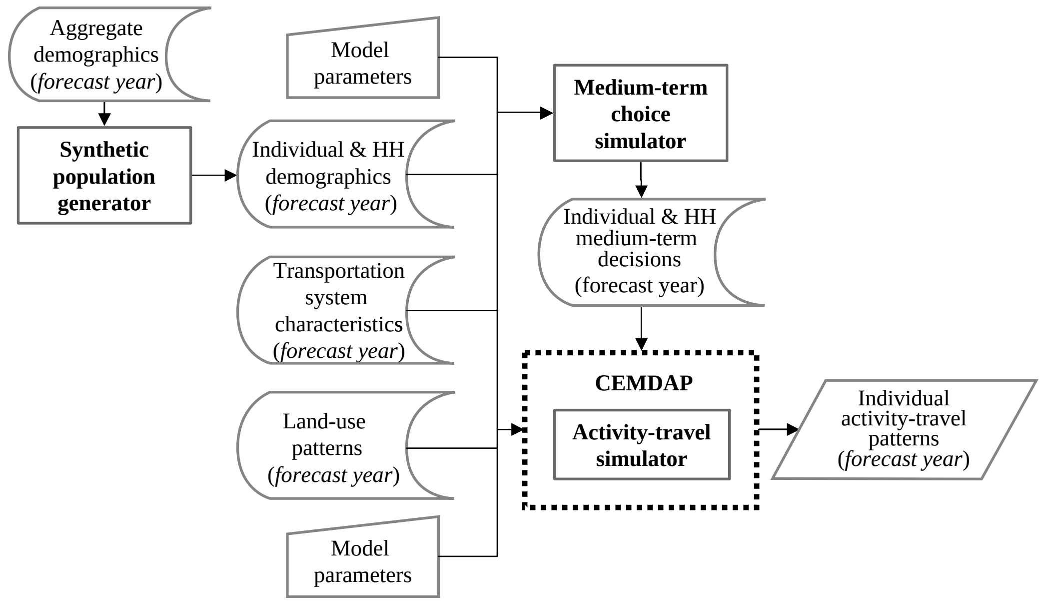

FIGURE 4 Overview of CEMDAP.

A medium-term choice simulator, currently external to CEMDAP, uses the input data and model parameters to predict medium-term choices for the synthetic population that include residential location, employment status, workplace location (for workers), and car ownership. Finally, the input data, medium-term decisions, and estimated model parameters are used by the econometric models embedded within CEMDAP to simulate the choice behaviors of households and individuals in the forecast year. The outcome of the simulation is the activity-travel patterns of individuals in the forecast year.

It should be emphasized that the development of CEMDAP goes beyond a once-off implementation of a modeling system calibrated for any specific region. Rather, the software has been developed to meet a number of broader objectives:

- To provide a friendly user interface that allows model parameters to be respecified for policy analysis or for deployment to any study region after appropriate reestimation of the model components using local data;
- To provide a generic library of routines for microsimulation to support rapid implementation of variants of the modeling system outlined earlier, which may be systems of different model hierarchy or models with different econometric structure; and
- To provide a software system in which future modifications, such as integration with population-update and household long-term choice models, can be easily accommodated.

Various aspects of the software development efforts are discussed in detail in the following sections.

System Architecture

CEMDAP was developed using the object-oriented (OO) paradigm. Through the process of OO analysis, a number of major entities involved in the microsimulation of activity-travel patterns were identified to arrive at the OO design for CEMDAP (see Figure 5). The system architecture includes the input database, the data object

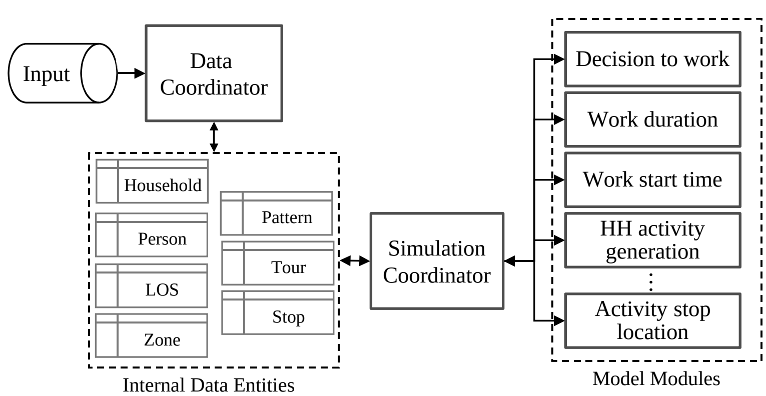

FIGURE 5 Software architecture of CEMDAP.

coordinator, the internal data entities, the modeling modules, and the simulation coordinator.

Input Database

The simulation of activity-travel patterns is a data-intensive exercise. Three sets of data are required: disaggregate socioeconomic characteristics of the population, aggregate zonal-level land use and demographic characteristics, and zone-to-zone transportation system LOS characteristics by time of day. These input data are organized into a relational database. Through the open database connectivity (ODBC) interface, CEMDAP can then access the data from database management systems such as Microsoft Access to alleviate data management operations within CEMDAP.

Data Object Coordinator

The data object coordinator is the component responsible for establishing the ODBC with the external database that contains the input data. It extracts the content and structural information of the data tables and converts data into their corresponding structures as used within CEMDAP.

Data Entities

Data entities are the main data structures that CEMDAP operates upon internally. Instances of household, person, LOS, and zone entities are created by the data object coordinator from the input data. The remaining entities (pattern, tour, and stop) are created by the simulation coordinator as required during the simulation process.

Modeling Modules

Each modeling module in the system corresponds to a behavioral component model in the framework described earlier. Although the component models are many (there are a total of 30 different models in CEMDAP), they are derived from a limited number of econometric structures. Currently, five types of econometric models are implemented in CEMDAP: regression, hazard duration, multinomial logit, ordered probit, and location choice (with probabilistic choice set generation). Each decision variable is associated with an instance of one of these five modeling modules. For example, mode choice is associated with an instance of the multinomial logit modeling module. Once a module is configured via the user interface, it possesses knowledge about the econometric structure and all the relevant parameters required to produce the probability distribution for the given variable. When called upon, the module executes a forecasting algorithm to predict the corresponding choice.

Simulation Coordinator

The simulation coordinator is responsible for controlling the flow of the simulation. It coordinates the logic and sequence in which the modeling modules are called. Data entities are created and manipulated as the corresponding choice outcomes are predicted. The simulation coordinator also performs any consistency checks as required.

Simulation Sequence

CEMDAP takes a sequential approach (i.e., one household at a time) to simulating the activity-travel patterns of individuals in the population. During each iteration, the input data for a particular household and all its adult members are loaded into the system. The generation-allocation model system is first applied to the household. The scheduling model systems are then applied to each of the household adults, with the workers processed before the nonworkers. Application of the scheduling system involves the sequential application of its three components: the pattern-level system, the tour-level system, and the stop-level system. Consistency check routines are implemented within the tour- and stop-level systems to ensure that temporal constraints are satisfied in the prediction of tour or activity stop durations. Once the simulation is complete for the given household, the activity-travel patterns of the household members are recorded before the next household is processed [complete details of the consistency checks and scheduling system are available elsewhere (*17*)].

Simulation Mechanism

In the preceding discussion on simulation sequence, the phrase "application of the scheduling system" refers to the process of stepping through each of the modeling module instances in the system to predict the corresponding choice outcome. There are two aspects to the prediction process: the determination of each individual decision instance (i.e., each component model) and the integration of the different decision instances into one final activity-travel pattern.

A simple approach to predicting individual decision instances involves selecting the alternative with the highest utility for each of the model components with discrete outcomes. Continuous choice variables may be assigned the expected value predicted by the model. The disadvantage of this methodology is that it introduces systematic bias in the outcome of each modeling step (*18*). Consequently, the cumulative prediction errors for large modeling systems that include several model components, such as the system implemented in CEMDAP, can be quite significant.

An alternative approach is to develop a full decision tree in which the probabilities of all the alternatives are carried over to the root node. The chosen set of alternatives can be subsequently determined by extracting the path with the highest path probability in the decision tree. Since the probabilities for all the alternatives for all choice instances need to be carried until the end, this approach can get computationally intensive for a large tree. Moreover, decision trees require discrete choice instances and cannot handle models with continuous choice outcomes.

The simulation mechanism adopted in CEMDAP eliminates the bias of the first approach while avoiding the computational complexity of the latter approach. It differs from the latter approach in that the choice outcome from each model is uniquely determined and carried over to the next model component. In the case of discrete choices, the chosen alternative is determined by partitioning the unit interval into as many segments as the number of alternatives. The length of each segment is specified to be equal to the probability of choice predicted for the corresponding alternative. Subsequently, a random draw is taken from the uniform distribution, and depending on the segment of the unit interval in which it falls, the corresponding alternative is declared as the chosen alternative. For the continuous choice instances, the choice is determined by a random draw from the probabilistic distribution of the choice variable defined by the associated econometric model. Thus, it is ensured that the chosen continuous outcome is not the same for all observationally similar decision makers. A comprehensive discussion of the simulation mechanism may be found elsewhere (*12*).

User Interface

The main interface for CEMDAP is a window framework with menu items that provide a means of assessing various functions of the software. Accessible through the menu are a set of model editors, one model editor corresponding to each of the model components in the activity-based travel analysis framework. The editors allow the user to configure the model specifications. The information collected in the editors is transferred to the corresponding modeling modules. In order for the system to "remember" model configurations from one run to the next, the information collected from the model editors is saved into an ASCII file, which can be loaded into the system whenever required.

The main menu of the software also provides a user-friendly diagrammatic interface, composed of dialog boxes and buttons, that guides the user through the model configuration process. This interface integrates the model editors using the framework discussed in the section on representation and modeling framework.

SOFTWARE DEPLOYMENT

In the following discussion, an overview of the different steps involved in running the software is provided, followed by a discussion of policy evaluations using CEMDAP and an actual application of the software to the DFW area.

Predicting Activity-Travel Patterns with CEMDAP

Three major steps are involved in predicting activity-travel patterns using CEMDAP. First, the different model components that constitute the overall modeling framework must be estimated for the study region using local travel survey data. The model parameters must then be input to the simulator using the software's graphical user interface. Second, the necessary input data must be prepared. These data are in the form of an Microsoft Access database with one table for each type—household, person, zonal, and LOS—in the planning year. One of the methods that can be employed to obtain detailed individual and household sociodemographics of the population in the planning year is synthetic population generation. The LOS data may be specified at any level of temporal resolution (i.e., they are not restricted to only peak and off-peak measures). In the third and final step, the simulation is actually run after the model parameters and the input database are loaded into the software using the graphical user interface. The output from the microsimulator is in the form of predicted activity-travel patterns for all the individuals in the synthetic population written out to a prespecified ASCII file.

Policy Testing

In addition to using CEMDAP to predict the activity-travel patterns of a population, it can also be used to assess the impacts of various transportation control measures (TCMs) and policy scenarios (including noncapital improvement measures such as ridesharing incentives, congestion pricing, and employer-based demand management schemes) on the activity-travel characteristics of the population. This assessment is achieved by comparing the simulated patterns for the base case against those for the proposed scenario in which the appropriate TCM has been implemented. In general, most TCMs can be implemented in CEMDAP using one or more of the following methods: (*a*) modifying input data such as land use, LOS, or individual characteristics (e.g., work flexibility); (*b*) using externally calibrated models with different explanatory variables or different sensitivities to existing variables; or (*c*) modifying the software code to constrain certain decisions either randomly or on the basis of some rule.

DFW Application

For an application of CEMDAP to predict activity-travel patterns and evaluate policy actions at both the disaggregate (individual) and aggregate (entire population) levels, a policy action is evaluated that concerns an early release from work with the intent of reducing travel during the peak period. The disaggregate policy analysis examines the behavioral response of a single worker when released early from work. The aggregate policy analysis examines overall changes in the activity-travel patterns of the entire population of the study area when a fraction of workers are released early from work. Both these analyses apply the system of econometric models embedded in CEMDAP, which were estimated using the 1996 DFW travel survey data [the model specifications and parameters obtained for the DFW area are documented elsewhere (*19*)]. The aggregate example uses as input synthetic data generated for the DFW area, and the disaggregate example uses the characteristics of a randomly selected individual worker.

In the implementation of policy testing at the disaggregate level, 50 simulation runs were undertaken for each of the base and policy cases. For all simulations runs, the work start time was fixed at 8:00 a.m. The work end time was fixed at 5:00 p.m. for the base-case simulations and at 2:30 p.m. for the policy scenario. The simulation experiment reveals several interesting and intuitive results. The policy action results in an increase in the probability that this individual will undertake nonwork activity stops during the day. This finding is indicated by the observation that 50% of the patterns generated in the policy case have one or more nonwork activity stops when compared with 44% in the base case. It was found that these stops most likely are made during the WH commute (28% of the patterns generated in the policy case and 16% of the patterns for the base case have WH commute stops). The individual is also found to be more likely to undertake AW tours during the policy case when compared with the base case. Further, the average duration of AW tours is also found to be greater in the policy case, presumably because of increased availability of time after work. In summary, this experiment suggests that the individual chosen for analysis is quite likely to respond to the policy action by either undertaking additional activity stops during the WH commute or by investing longer durations in AW tours.

A subsample of 1,000 households (with a total of 2,146 adults, 1,473 of whom are employed) from the entire synthetic population generated for the DFW area was used for the aggregate policy test experiment. The base-case simulation run indicated that about 38% of workers start work between 7:00 and 9:00 a.m. and end work between 4:00 and 6:00 p.m. About 50% of all work episodes were found to end between 4:00 and 6:00 p.m. Such a high concentration of travel during short periods can congest the highway network. The policy action explored releases a random sample of 25% of workers (whose work start times were originally between 7:00 and 9:00 a.m. and end times between 4:00 and 6:00 p.m.) 2.5 h early from work. The simulations were used to explore overall changes to the travel patterns of all workers. The results indicate that more workers undertake activity stops in the policy scenario and these stops are likely to be during the WH commute (17.2% of workers in the policy case make WH commute stops, up from 16% in the base case) or during AW tours (46.6% of the workers in the policy case undertake AW tours, up from 45.8% in the base case). The WH commute duration and the duration of the AW tours is also found to be higher, on average, in the policy case, presumably because of increased time availability to workers released early from work.

In summary, the experiments demonstrate that an employer-based demand management strategy such as an early release from work can significantly affect the overall activity-travel patterns of workers. Specifically, such a strategy could lead to the increased likelihood of stops undertaken after work. Hence, it would be erroneous to assume that the original patterns will simply be translated back in time. This study highlights the importance of explicitly accommodating temporal constraints and time-of-day effects in modeling activity-travel choices. In addition, in examining the impact of such policy actions, it would be desirable to undertake both disaggregate and aggregate studies. Disaggregate policy analysis can help identify the target population for various policy actions by examining probable responses at the individual level. The aggregate analyses can help quantify the extent of the impact of the policy action when implemented in a particular area. The experiments undertaken highlight the applicability of CEMDAP to both types of studies.

CONCLUSION

An overview is provided of the development of CEMDAP, a microsimulator designed to comprehensively model the daily activity-travel patterns of individuals. The simulator implements a predefined econometric modeling system that represents choice behavior, but no model parameters calibrated for any specific region are hard-wired in the system. Instead, CEMDAP is a flexible tool that can be configured to any study region for which the required input data and model parameters are available. The system generates as output the predicted activity-travel patterns for all individuals in the simulation sample. Traffic assignment methods can be applied to determine travel demand patterns on the network. Policy analysts can employ CEMDAP to assess the impact of various TCMs by one or all of the following methods: adjusting input data, modifying model parameters, and imposing explicit choice constraints within the program.

A demonstration study is discussed that predicts activity-travel patterns using model parameters estimated for the DFW area, in Texas. A policy experiment was performed to study changes to these patterns as a consequence of an employer-based demand management strategy. The results clearly indicate significant changes to the overall activity-travel behavior of a worker as a consequence of early release from work, thereby highlighting the need to explicitly account for temporal constraints and time-of-day effects in modeling travel choices. Moreover, the exercise demonstrates that an activity-travel microsimulator such as CEMDAP allows policy actions to be analyzed in ways generally not possible with the conventional four-stage modeling approach.

The development of CEMDAP is an ongoing effort and the system is being enhanced along several directions, including (*a*) enhancement of software, such as updating model modules and developing user interfaces to aid in policy analysis; (*b*) expansion of the model framework by incorporating demographic evolution processes and land use forecasting models; and (*c*) integration with a disaggregate dynamic route choice simulator to convert predicted activity-travel patterns into link flows.

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