Comprehensive Econometric Microsimulator for Daily Activity-travel Patterns: Recent Developments and Sensitivity Testing Results

S. Srinivasan
Assistant Professor, University of Florida – Gainesville

J.Y. Guo
Assistant Professor, University of Wisconsin – Madison

C.R. Bhat
Professor, The University of Texas at Austin

R. Copperman, N. Eluru, A. Pinjari, I. Sener
PhD Students, The University of Texas at Austin

1. Introduction

CEMDAP, or the Comprehensive Econometric Microsimulator for Daily Activity-travel Patterns, is a continuous-time activity-travel prediction software currently being evaluated by applying to the Dallas-Fort worth Metropolitan area. This paper describes the current state of the overall work-in-progress and the future tasks planned in the refinement and testing of the software system[1]. The rest of this paper is organized as follows. Sections 2 and 3 describe the latest version (v 0.3) of CEMDAP. Specifically, Section 2 provides an overview of the econometric modeling framework incorporated within CEMDAP v 0.3. Section 3 is focused on the software development efforts. Section 4 presents the sensitivity testing undertaken using version 0.2 of the software. Finally, Section 5 summarizes the paper and identifies the areas of on going work and tasks planned for the immediate future.

2. Modeling Framework

CEMDAP is based on a system of econometric models. Each model corresponds to the determination of one or more of activity/travel attributes. These models are applied in a systematic sequence to generate the daily activity and travel patterns of all members (both adults and children) in each household in the study area. The overall prediction procedure (for a household) is subdivided into two major sequential steps: (1) the prediction of activity generation and allocation decisions and (2) the prediction of activity scheduling decisions.

The first step predicts the decisions of household members to pursue various activities during the day. This step, in turn, comprises the following three sequential steps (each of which may comprise one or more models):

1. Work and school activity participation and timing decisions.
2. The generation of children's travel needs (such as school and leisure) and allocation of escort responsibilities to parents.

[1] All CEMDAP documents are available at http://www.ce.utexas.edu/prof/bhat/FULL_CEMDAP.htm

3. The generation of independent activities (such as shopping, recreation, and personal business) for personal and household needs.

The second step predicts the sequencing of the activities generated in the previous step, accommodating the space-time constraints imposed by work, school, and escort of children activities. This major step broadly comprises the following sequential steps (each of which may comprise one or more models):

1. Scheduling the commutes for each worker in the household (mode, # stops, and for each stop, the activity type, activity duration, travel time, and location).
2. Scheduling the drop-off tour for the non-worker escorting children to school.
3. Scheduling the pick-up tour for the non-worker escorting children from school.
4. Scheduling the commutes for school-going children (mode and duration).
5. Scheduling the joint tour for the adult pursuing discretionary activity jointly with children (departure time, activity duration, travel duration, and location).
6. Scheduling the independent home-based tours and work-based tours for each worker in the household (number of tours, home-stay duration before tours, tour mode, number of stops in each tour, and for each stop, the activity type, activity duration, travel time, and location).
7. Scheduling the independent home-based tours for each non-worker in the household (number of tours, home-stay duration before tours, tour mode, number of stops in each tour, and for each stop, the activity type, activity duration, travel time, and location).
8. Scheduling the discretionary activity tours for each child in the household (departure time, activity duration, travel duration, and location).

This new modeling system enhances the previous system embedded in CEMDAP v 0.2 in several ways. First, the new system is developed at a finer spatial resolution and applied to a 4874 zone system for the Dallas/Fort-Worth (DFW) area in Texas. Second, the activity-travel patterns of children (persons under 16 years of age) are now explicitly modeled and forecasted. Third, the interdependencies between the travel patterns of children and their parents (such as escort to and from school and joint participation in discretionary activities) are explicitly accommodated. Finally, for estimation of the models, the raw survey data obtained for the DFW area were re-processed to create a larger sample and all the model components (over fifty in all) were re-estimated. The reader is referred to Guo et al. (2005) for detailed descriptions of the modeling framework , the econometric structure of each model component, and the sequential prediction procedure.

3. Software Implementation

The goal of the CEMDAP software development process is to provide a microsimulation platform that can be easily configured for different study areas, for which the level of data availability and, consequently, the degree of modeling system complexity often vary.

The software design philosophy is to create a generic library of routines that form the building blocks of an activity-based travel demand modeling system so that variants of modeling systems can be rapidly implemented. These building blocks include, for example, a number of Modeling Modules that are routines developed for applying different types of econometric models. The Modeling Modules can then be reused and reconfigured to simulate the choice outcome of various behavioral dimensions. Configuration of the Modules is achieved through window-based user interface components that support the saving and loading of model parameters. Another type of the system building blocks is the Simulation Coordinator, which controls the logic and sequence in which the Modeling Modules are executed to generate the activity and travel patterns for a given household. The Modules are 'plugged' into the Coordinators in the way that any Module can be modified, can have its parameters changed, and can be entirely replaced by a different Module without introducing changes to the rest of the system. The reader is referred to Bhat et al (2003) for details on the implementation of CEMDAP v 0.2.

CEMDAP v 0.3 is significantly improved from version 0.2 in the following ways:

1. In order to accommodate the increased input database size resulting from the more detailed zoning system, CEMDAP now uses Postgres, as opposed to Microsoft Access, to run queries about the input database. Postgres is known to be stable under large data loads and is a open source database software released under the BSD (Berkley Software Distribution) license.
2. The system has built-in data caching routines to store frequently-accessed data items in RAM (random access memory) so as to reduce the number of queries and disk accesses.
3. A new Model Module is added to the system for jointly simulating work start and end times.
4. Separate Simulation Coordinators are implemented to control the simulation sequence for different household types (households with or without children, individuals who go to work, or individuals who go to school).
5. The system computational efficiency is enhanced by running the simulation over multiple threads.

4. Preliminary Sensitivity Testing

This section discusses preliminary sensitivity testing undertaken using a recent but older version of CEMDAP. Specifically, we examined aggregate changes to the predicted activity-travel patterns under the following scenarios: 10% and 25% increase in in-vehicle travel times (IVTT) and 10% and 25% decrease in IVTT. The intent of this exercise was to examine the reasonableness of predictions. We plan to conduct similar (but more exhaustive) tests using the newer version of CEMDAP. Further, during this planned exercise, we will also compare the outputs from CEMDAP with the outputs from the four-step modeling system currently employed by NCTCOG.

The activity-travel patterns were predicted for the entire synthetic population (3,452,751 adults from 1,754,674 households) for the base case and each of the above four scenarios and compared. The impact of changes in IVTT on the aggregate activity travel patterns were examined using several measures including: (1) trip frequency (Section 4.1), (2) person miles of travel (PMT) and vehicle miles of travel (VMT) (Section 4.2), and (3) person hours of travel (PHT) (Section 4.3).

4.1. Changes to trip frequency

A 10% increase in IVTT decreases the total number of trips by 1% and a 25% IVTT increase decreases the total number of trips by 2.4% (Table 1). A 10% decrease in IVTT increases the total trips by 1.16% and a 25% IVTT decrease increases the number of trips by 3.1%. We also find that the frequency of home-based work trips is least sensitive to IVTT changes.

Table 1. Impact of IVTT on trip frequency

	Home-based Work		Home-based Other		Non Home-Based		Overall	
	# trips*	% diff.	# trips*	% diff.	# trips*	% diff.	# trips*	% diff.
Base Case	3.70		5.58		2.35		11.62	
10% Increase	3.70	0.08	5.51	-1.27	2.29	-2.30	11.50	-1.05
25% Increase	3.71	0.24	5.41	-3.05	2.23	-5.08	11.34	-2.42
10% Decrease	3.69	-0.22	5.66	1.49	2.41	2.52	11.76	1.16
25% Decrease	3.68	-0.59	5.80	4.06	2.51	6.83	11.99	3.14

* Number of trips is in millions.

On further disaggregating the trip by destination activity purpose, the frequency of trips for social/recreation, shopping, and personal business are found to be the most sensitive to changes in IVTT (IVTT impacts generation of activities for these purposes via the accessibility measure).

4.2. Changes to PMT and VMT

An increase in IVTT decreases the overall PMT (Table 2) and VMT (Table 3), whereas a decrease in IVTT increases the overall PMT and VMT. As would be expected, we find that the PMT and VMT for home-based work trips show the least sensitivity to changes in IVTT. In contrast, the distances traveled for non-work purposes (especially, shopping, social/recreation, and personal business) are impacted by transportation level of service. These changes are consistent with intuitive expectations as the home and work locations are fixed in the short-term.

Table 2. Impact of IVTT on PMT

	Home-based Work		Home-based Other		Non Home-Based		Overall	
	PMT*	% diff.	PMT*	% diff.	PMT*	% diff.	PMT*	% diff.
Base Case	54.03		83.34		27.53		164.91	
10% Increase	54.03	-0.01	77.21	-7.35	24.76	-10.05	156.01	-5.40
25% Increase	54.03	0.00	69.21	-16.95	21.56	-21.69	144.81	-12.19
10% Decrease	53.96	-0.13	90.65	8.77	30.91	12.26	175.52	6.43
25% Decrease	53.80	-0.44	104.02	24.81	37.53	36.30	195.34	18.46

* PMT is in millions of miles.

Table 3. Impact of IVTT on VMT

	Home-based Work		Home-based Other		Non Home-Based		Overall	
	VMT*	% diff.	VMT*	% diff.	VMT*	% diff.	VMT*	% diff.
Base Case	44.84		58.45		22.00		125.30	
10% Increase	44.85	0.02	54.07	-7.50	19.80	-10.03	118.71	-5.26
25% Increase	44.83	-0.02	48.40	-17.19	17.24	-21.64	110.48	-11.83
10% Decrease	44.81	-0.08	63.65	8.88	24.70	12.25	133.15	6.27
25% Decrease	44.65	-0.43	73.25	25.32	30.04	36.53	147.95	18.07

* VMT is in millions of miles.

4.3. Changes to PHT

The impacts of changes in IVTT on total person hours of travel are presented in Table 4. An increase in IVTT increases the person-hours of travel for work and decreases the PHT for non-work purposes (especially shopping and social/recreation), resulting in an overall increase in PHT. A decrease in IVTT reduces work PHT and increases the non-work PHT, resulting in an overall decrease in PHT.

Table 4. Impact of IVTT on PHT

	Home-based Work		Home-based Other		Non Home-Based		Overall	
	PHT*	% diff.	PHT*	% diff.	PHT*	% diff.	PHT*	% diff.
Base Case	1.68		3.12		0.79		5.59	
10% Increase	1.77	5.53	3.10	-0.73	0.78	-0.74	5.66	1.15
25% Increase	1.91	13.89	3.06	-1.89	0.78	-1.34	5.76	2.93
10% Decrease	1.58	-5.73	3.15	0.94	0.80	0.84	5.53	-1.08
25% Decrease	1.44	-14.13	3.21	2.64	0.81	2.67	5.46	-2.39

* PHT is in millions of hours.

5. Summary

The CEMDAP project represents a significant effort in the development and implementation of an activity-based travel forecasting system. The recent efforts by the researchers have been focused on incorporating several enhancements (such as modeling the travel patterns of children and incorporating children-parent interactions) to the overall modeling framework, and applying the framework to an expanded 4874 zone system in the Dallas-Fort Worth area. All the models have been re-estimated for this new zoning system using household travel survey, and disaggregate land use and inter-zonal level-of-service data, from the Dallas Fort worth area.

The researchers are currently engaged in the implementation and integration testing of the software for the expanded and enhanced software version. Simultaneously, data inputs are also being assembled for evaluating and sensitivity-testing the software outputs.

The tasks planned for the immediate future include the following: (1) comparison of the travel patterns predicted for the estimation sample against the observed patterns in the activity-travel survey, (2) complete software run for the entire baseline population (synthetically generated for the year 2000), (3) evaluation of sampling strategies, (4) comparisons of CEMDAP outputs with those from four-step models currently employed by NCTCOG, (5) validations against ground counts and other measures, (6) sensitivity tests and comparisons of CEMDAP and NCTCOG results, and (7) predictions for a future year and corresponding comparisons with NCTCOG model results. Many of these tasks will be completed by the time of the conference.

Reference

Bhat, C.R., J. Guo, S. Srinivasan, and A. Sivakumar, "Activity-Based Travel Demand Modeling for Metropolitan Areas in Texas: Software-related Processes and Mechanisms for the Activity-Travel Pattern Generation Micro-simulator," Report 4080-5, prepared for the Texas Department of Transportation, October 2003.

Guo, J.Y., S. Srinivasan, N. Eluru, A. Pinjari, R. Copperman, and C.R. Bhat, "Activity-Based Travel-Demand Analysis for Metropolitan Areas in Texas: CEMSELTS Model Estimations and Prediction Procedures, 4874 Zone System CEMDAP Model Estimations and Procedures, and the SPG Software Details," Report 4080-7, prepared for the Texas Department of Transportation, October 2005.

Acknowledgements: The authors appreciate the help of the North Central Texas Council of Government (NCTCOG) travel modeling team in the CEMDAP sensitivity testing efforts, for providing the data for model estimation, and for their overall support of this research effort. The research is sponsored by the Texas Department of Transportation.