Transitioning to Activity-Based Models: Learning from the Southern California Experience

presented to
Florida Model Task Force Meeting

presented by
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Experience with **SimAGENT**

**Simulator of Activities, Greenhouse gases, Energy, Networks, and Travel**

- Setting and Policy Context
- Sensitivity Testing and Validation Exercises
- Salient Elements
- Data Needs for Developing ABMs
- Considerations and Pathways
SCAG Context

- Six counties – 188 cities – 14 subregions
- 38,000 square miles with 19 million residents
- Nation’s largest region in terms of both population and size - socially, culturally and economically diverse
- 15th largest economy in the world
SimAGENT Vision for SCAG ABM

- Comply with the California Transportation Commission (CTC) 2008 guidelines for RTPs; responsive to California SB375

- Create an activity-based model that can address wide range of policies, including:
  - **Economic analysis**: location-based welfare, development impacts, maintain vibrancy
  - **Equity analysis**: change in welfare by household income class and minority populations
  - **Sensitivity analysis**: different parameters characterizing inputs and policy measures
  - **Pricing analysis**: evaluate different transportation pricing options, including corridor pricing (toll roads and managed lanes), cordon pricing, area pricing, congestion pricing, and parking pricing
  - **Intermodal and Multimodal policy analysis**: assess effectiveness of alternatives to traditional roadway system expansion options
Why Transition to Activity-Based Models

- Explicitly represent inter-dependencies, relationships, and constraints that exist among agents and entities
  - Relationships across trips in a tour/chain
  - Interactions among household members (task allocation and joint activity/trip engagement)
  - Time-space interactions and constraints
  - Institutional and modal constraints

- High-fidelity modeling
  - Disaggregate microsimulation of activity-travel patterns
  - Who is affected by policy/action, when are they affected, and how are they affected?
  - Representation of time and space as a continuum
  - Model behavior at the level of the individual choice-maker
Policies and Issues of Interest to SCAG

- Changes in land use patterns
- Congestion pricing
- HOV/HOT Lanes
- Parking policies, pricing, and duration/usage
- Transit fare and service changes; new modes
- Alternative work arrangements
- Changes in socio-economic characteristics
- Alternative fuel vehicle purchase/usage policies \(\rightarrow\) emissions implications
Sensitivity Testing and Validation Exercises
CEMDAP: A Policy Responsive Tool

- Holistic model system with closely inter-related models
- Cascading effect with secondary and tertiary changes occurring throughout the activity schedule of the day
- Changes in the activity-travel pattern of one individual in a household affect activity-travel patterns of other household members
- Also recognizes the presence of constraints in activity-travel patterns that may result in little or no change
- Enhanced sensitivity to LU, built environment and development patterns, and multi-modal transportation policies – team has pioneered the development of time-sensitive, fine-scale, accessibility measures
CEMDAP: A Continuous-Time ABM

3 a.m. on day d

Before-Work Tour

Home-Stay Duration

S₁

S₂

Arrive back home

Home-Stay Duration

Work-Stay Duration

Temporal fixity

Leave home for non-work activities

Arrive back home

Leave for work

Arrive at work

Leave work

Work-Based Tour

Temporal fixity

Work-Stay Duration

S₃

After Work Tour

Home-Stay Duration

Home-Stay Duration

S₄

S₅

S₆

3 a.m. on day d+1

Arrive back at work

Leave work

Arrive back home

Leave for non-work activities

Arrive back home

Home-Stay Duration
CEMDAP Sensitivity

- Work Start & End times
  - Auto IVTT & Cost

- Determining Households with Non-zero OH Non-Work Duration
  - Hansen Type Accessibility Measures: Retail and Service Employment Accessibility, Population Accessibility
  - Several Opportunity-based accessibility Measures

- Non-work Independent and Joint Activity Participation Decisions
  - Hansen Type Accessibility Measures: Retail and Service Employment Accessibility, Population Accessibility
  - Several Opportunity-based accessibility Measures

- Number of Non-Commutte Tours
  - Several Opportunity-based accessibility Measures
CEMDAP Sensitivity (continued)

Commute Mode Choice Decisions
- IVTT, OVTT, Cost
- Several Opportunity-based accessibility Measures

Non-Commute Mode Choice Decisions
- Hansen Type Accessibility Measures
- Several Opportunity-based accessibility Measures

Number of Stops in Tour
- Several Opportunity-based accessibility Measures
- IVTT for commute tours

Stop Location Decisions
- Hansen Type Accessibility Measures: Retail and Service Employment Accessibility, Population Accessibility
- Several Opportunity-based accessibility Measures
- Generalized cost
Policy Sensitivity Illustration

Generation Allocation Model System

1) Commute mode
2) Number of commute stops
3) Presence and number of after-work, work-based, and before-work tours and stops
4) All aspects of each stop in each tour (including timing, location, and activity duration)

Scheduling Model System
# Sensitivity Analysis for LA Region

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
<th>Changes to Base Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Scenario</td>
<td>2003 is the analysis year</td>
<td>---</td>
</tr>
<tr>
<td>15% Increase in Population and</td>
<td>Population and employment in the study area are increased by 15%</td>
<td>The population and employment density measures were increased by 25%</td>
</tr>
<tr>
<td>Employment Densities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100% Increase in Cost—Drive Alone</td>
<td>A 100% increase in cost for drive-alone for all time periods</td>
<td>LOS tables were altered by multiplying the drive alone auto cost by 2 in the a.m., p.m., and off-peak files</td>
</tr>
<tr>
<td>Mode</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$2 Increase in CBD Cost—Auto Mode</td>
<td>A $2 charge is imposed on the auto trips that enter/exit the CBD during a.m. and p.m. peak periods</td>
<td>LOS tables were altered by adding an additional $2 to the existing cost for auto trips that originate or end in the CBD in the a.m. and p.m. peak files</td>
</tr>
<tr>
<td>and Peak Periods</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25% Increase in IVTT—Auto Mode and</td>
<td>A 25% increase in IVTT for the drive-alone and shared ride for the a.m. and p.m. peak time periods</td>
<td>LOS tables were altered by multiplying the auto IVTT by 1.25 in the a.m. and p.m. peak files</td>
</tr>
<tr>
<td>Peak Periods</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Policy Analysis

Employer-based demand management scheme

**Base Case**

8 AM  

5 PM  

Work-based duration = 9 hours

**Policy Case**

8 AM  

2:30 PM

Work-based duration = 6.5 hours
# Policy Analysis

## Simulation results

### Alternate activity-travel patterns

<table>
<thead>
<tr>
<th>Base Case</th>
<th>Pattern</th>
<th>Policy Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>H → W → H</td>
<td>16</td>
</tr>
<tr>
<td>13</td>
<td>H → W → S → W → S → H</td>
<td>11</td>
</tr>
<tr>
<td>06</td>
<td>H → W → S → W → H</td>
<td>03</td>
</tr>
<tr>
<td>03</td>
<td>H → W → H → S → H</td>
<td>05</td>
</tr>
<tr>
<td>01</td>
<td>H → W → S → H</td>
<td>09</td>
</tr>
<tr>
<td>06</td>
<td>All Other Patterns</td>
<td>06</td>
</tr>
</tbody>
</table>
### Drive Alone Cost Increase by 100% (LA Region)

<table>
<thead>
<tr>
<th>Overall Pattern</th>
<th>Commute and additional tour</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Base Scenario</strong></td>
<td></td>
</tr>
<tr>
<td>Total mileage (miles)</td>
<td>35.21</td>
</tr>
<tr>
<td><strong>HW Commute</strong></td>
<td></td>
</tr>
<tr>
<td>Number of non-work stops</td>
<td>0</td>
</tr>
<tr>
<td>Mode</td>
<td>Drive alone</td>
</tr>
<tr>
<td>Activity at non-work stops</td>
<td>-</td>
</tr>
<tr>
<td><strong>WH Commute</strong></td>
<td></td>
</tr>
<tr>
<td>Number of non-work stops</td>
<td>0</td>
</tr>
<tr>
<td>Mode</td>
<td>Drive alone</td>
</tr>
<tr>
<td>Activity at non-work stops</td>
<td>-</td>
</tr>
<tr>
<td><strong>Tour 1</strong></td>
<td></td>
</tr>
<tr>
<td>Number of stops</td>
<td>1</td>
</tr>
<tr>
<td>Mode</td>
<td>Drive alone</td>
</tr>
<tr>
<td>Activity at stops</td>
<td>Eat out</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Policy Scenario</strong></th>
<th>Commute tour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total mileage (miles)</td>
<td>35.21</td>
</tr>
<tr>
<td><strong>HW Commute</strong></td>
<td></td>
</tr>
<tr>
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<td>-</td>
</tr>
<tr>
<td><strong>WH Commute</strong></td>
<td></td>
</tr>
<tr>
<td>Number of non-work stops</td>
<td>1</td>
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<td>Mode</td>
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<tr>
<td>Activity at non-work stops</td>
<td>Eat out</td>
</tr>
</tbody>
</table>
Drive Alone Cost Increase by 100% (LA Region)

Base Scenario

Policy Scenario

Drive Alone Cost Increase by 100% (LA Region)

Base Scenario

Policy Scenario
Validation Analysis

- No ad-hoc model calibration process using adjustment factors, modifications of constants, etc.
  - Examine model specification/structure and revise until survey data trends are accurately replicated

- Model validation based on several methods and measures

- True validation involves extensive assessment based on sensitivity and scenario analysis
  - Socio-economic scenarios
  - Social equity and environmental justice analysis
  - Transportation network capacity scenarios
  - Pricing scenarios
  - Vehicle technology/holdings scenarios
  - Homeland security and emergency management scenarios
  - Travel demand management strategy scenarios
Evaluate “Quality of Life”

- Activity-based model system capable of producing composite numeric “quality of life” measure

- Time-use utility measure derived from daily activity-travel pattern
  - Based on time spent traveling to/from and at activities of different type
  - Very useful to understand changes in “quality of life” as a result of a system change or policy intervention
  - Critical to social equity and environmental justice analysis
Salient Elements
SimAGENT Based on CEMUS

**Base Year Inputs**

- Aggregate socio-demographics (*base year*)
- Activity-travel environment characteristics (*base year*)
- Policy actions
- Model parameters

**Forecast Year Outputs**

1. Synthetic population generator (*PopGen*)
2. Link volumes and speeds
3. Socio-economics, land-use and transportation system characteristics simulator (*CEMSELTS*)
4. Individual activity-travel patterns
5. Activity-travel simulator (*CEMDAP*)

**Linkages**

- Detailed individual-level socio-demographics (*base year*)
- Socio-demographics and activity-travel environment

21
Salient Features of CEMDAP

Temporal Resolution
- Continuous time scale (1 min for DFW/SCAG application)
- Level-of-service data can be provided at any temporal resolution (5 time-of-day periods for DFW/SCAG application)
- Explicitly considers time-space interactions/constraints
- Enables consideration of time-varying and dynamic pricing policies

Spatial Resolution
- Allows for any spatial resolution, and multi-scale spatial resolution

Activity Resolution
- Allows for any purpose resolution, and multiple resolution across market segments

Graphical User Interface
- Standard Windows-based user interface
- Allows user to modify model parameters
- Provides a friendly diagrammatic interface to help the user understand the logic of the system and the underlying models

Demonstration of CEMDAP Software
Adult-Child Interaction
An Interleaved Approach

Children's Pattern

- Go to School?
  - School Timing

Parent(s)' pattern

- Go to Work?
  - Work Timing

Mode to/from School

- Drive by parent

Allocate to Parent(s)

Adjust Work Timing of Parent(s)
Recent Advances in SCAG ABM

Joint Activity Participation

- Growing interest in accommodating joint activity participation across household members
- In conventional discrete choice frameworks, the need to generate mutually exclusive alternatives results in an explosion in choice sets
- Multiple Discrete-Continuous Extreme Value (MDCEV) allows us to tackle the problem by considering activity participation as a household decision
- MDCEV offers substantial computational and behavioral advantages
  - Employ one model to generate activity participation for all household members as opposed to one model per activity type and per person while simultaneously accommodating for joint activity participation
  - Accommodate substitution/complementarity in activity participation and household member dimensions
Example: 2 persons and 2 activity purposes – Single Discrete Case

<table>
<thead>
<tr>
<th></th>
<th>P1</th>
<th>P2</th>
<th>P1 P2</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>A1</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>A2</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>A1 A2</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

Each box represents an alternative.
Example: 2 persons and 2 activity purposes – Multiple Discrete Case

<table>
<thead>
<tr>
<th>A1 P1</th>
<th>A1 P2</th>
<th>A1 P1P2</th>
</tr>
</thead>
<tbody>
<tr>
<td>A2 P1</td>
<td>A2 P2</td>
<td>A2 P1P2</td>
</tr>
</tbody>
</table>

Each box represents an alternative

Total 7 alternatives versus 64 in traditional case
## Total choice set size comparison for 3 activity purposes

<table>
<thead>
<tr>
<th>Household Size</th>
<th>Single Discrete Model (MNL)</th>
<th>MDCEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>512</td>
<td>9</td>
</tr>
<tr>
<td>3</td>
<td>2097152</td>
<td>21</td>
</tr>
<tr>
<td>4</td>
<td>$3.52 \times 10^{13}$</td>
<td>45</td>
</tr>
<tr>
<td>5</td>
<td>$9.9 \times 10^{27}$</td>
<td>93</td>
</tr>
<tr>
<td>Total</td>
<td>$9.9 \times 10^{27}$</td>
<td>171</td>
</tr>
</tbody>
</table>

Once the number of activities increases, the difference will be even more stark!
Household Vehicle Fleet models

- Improves ability to forecast regional fleet mix and use
- Fundamentally important for travel demand modeling and transportation policy analysis

**Determinants of**

- Global Climate Change
- Fuel Consumption
- Green House Gas Emissions

**HOUSEHOLD'S NUMBER OF VEHICLES + VEHICLE TYPE CHOICE + MILEAGE**
Currently travel models are interfaced with EPA’s MOVES, or EMFAC, for emissions analysis

- Assumptions regarding vehicle fleet mix may not reflect local conditions

- No basis to forecast future vehicle fleet composition in response to changes in fuel prices, socio-economic shifts and policy actions
**MDCEV Model Approach**

- **MDCEV** – Multiple Discrete Continuous Extreme Value
  - Simple closed form structure for the probability expressions
  - Allows the choice of multiple alternatives

- A disaggregate vehicle typology which is virtually impossible in traditional choice models

- MDCEV model can incorporate the notion that:
  - Households own and use different vehicles for different functional purposes
  - Different individuals can have different preferences

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In short, MDCEV model framework offers an elegant, theoretically consistent, and econometrically integrated approach to model vehicle ownership, vehicle type, and vehicle usage decisions, and all of them simultaneously.
MDCEV

- Vehicle Type and Annual Mileage
- Primary Driver

MNL

- Vehicle Make Model

MNL (Travel Simulator in SimAGENT)

- Vehicle Type Model for Joint Tours in the HH
SimAGENT

For every auto tour

Output

Body Type

Vintage

Vehicle Make
Computational Techniques in CEMDAP

- Multi-threading/Parallel Processing

- Data Caching
  - PostgreSQL database with suitable indexing, caching of frequently used data items and hash tables for look up

- Sampling Analysis

- Constant (Pseudo) random numbers across different policy scenarios
  - Minimize the random simulation bias in policy analyses
  - Allows a disaggregate level assessment of policies
Evolving Data Collection and Availability to Support Activity-Based Modeling
Data for Estimation of ABMs

- **Core Behavior and Household Characteristics**
  - Other aspects – policy relevant (cars and costs, long term choices and lifestyle preferences, attitudes)

- **Other agents (firms, institutions, and developers)**

- **Landscape/Environment/Context**
  - Activity locations
  - Homes/Jobs/Schools
  - Availability over time
Data to Support ABMs

Core Survey (Household, Person, and Base Diary)

Figure 4 The Data Collection Overall Scheme
Multiple-Day Activity & Travel Diary

- Account for day-to-day variation in activity scheduling and travel and attempt to:
  - Identify shifting of tasks and activities from one day of the week to the next

- Design to capture the behavioral processes of scheduling activities, and planning and subsequent rescheduling modifications
GPS and GPS OBD

- Develop a database to correlate destinations to routes and identify a typology of different types of routes and stop making patterns
- Develop a route choice model
- Estimate the level and nature of misreported trips by different modes of the main two-day activity diary
- Verify day-to-day behavioral change in other survey components and day of the week effects and provide detailed operating characteristics of the household vehicles

**NOTE:** This component for persons carrying GPS devices (wearable GPS) can also be supplemented with an online diary and vehicle mounted GPS (week long to capture day to day variation) and On-Board Diagnostics devices (to identify driving patterns and correlate/link them with emissions models).
Residence, Workplace, and School Location Choice

- Critical survey component for behaviorally integrated land use activity-travel demand models
- In-depth survey to identify the determinants for each of the residential, workplace, and school choices
- Both primary locations and secondary locations should be examined in more detail than typical household surveys and data collected to estimate choice models for each facet
- Examine behavior retrospectively and prospectively
- Possibly add questions about personal biography of each household member using techniques that are not used by typical household surveys (e.g., ethnography)
In Depth Car Ownership Change and Car Assignment

- Identify the determinants for each of the car ownership, car type (e.g., new/used, model, make, and fuel type), and car assignment decisions.

- In the car assignment data collection, both the primary and secondary drivers should be identified.

- Identify determinants of changes in car ownership, type, and assignment of cars to household members.

- Particular emphasis should be given to policy controlled determinants (e.g., taxation, incentives).

- One approach to study this latter part is using combinations of revealed and stated preference surveys.
Data for Application of ABMs

- Information on all individuals and households of the study area for the base year
- Synthetic population generation supplemented with a series of other demographic models provide this data
- For a future year forecasting exercise, the inputs should consist of the future year synthetic population, land use, and level-of-service data
- Need ability to generate detailed input data (i.e., the synthetic population, level-of-service and land-use data) for future years
Data for Validation of Input Data

- The base year synthetic population inputs can be validated against the census data.

- To validate the input work locations, the home-work trip lengths and patterns can be matched against that in the census data.

- To validate the vehicle ownership inputs, census data and perhaps other sources such as motor vehicle department estimates of auto registrations can be used.
Data for Calibration and Validation of Activity-Travel Model Outputs

- Comparison with observed traffic patterns
- Desirable to have detailed traffic volume and speed data
  - land-use and level-of-service data
  - observed traffic volumes by vehicle class
  - spatio-temporal distribution of traffic
  - household activity and travel survey data
  - Census data
- Also use sensitivity analysis as basis for assessing model validity
Considerations and Pathways
What is Missing in Activity-Based Travel Models?

- Activity-based travel models account for intra-regional personal travel

- Need to combine personal travel estimated by ABM with other travel estimated by four-step or other model to get complete picture of travel demand in region
Approaches to Account for “Other” Travel

- Alternative approaches to combine sources of travel demand from different models

- In a traditional static traffic assignment context
  - Aggregate activity-travel records from ABM into OD matrices by time of day
  - Combine OD matrices across sources of travel as appropriate
  - Run traditional static traffic assignment procedures to obtain network flows

- In a dynamic traffic assignment (DTA) context, two options possible
  - Produce OD matrices by time of day from activity-travel records, combine with other OD matrices, and input to DTA model
  - Disaggregate other OD matrices into trip lists using time-of-day distributions from surveys/counts
  - Provide disaggregate trip lists/records to DTA model
Common Themes/Directions in ABM

- **Microsimulation**-based model system with activity-travel demand estimated for each agent
- **Enhancing behavioral realism**
  - Time-space interactions and constraints
  - Intra-household interactions – in particular, child-adult interactions
  - Treatment of time as a continuous (or near-continuous) entity
  - Activity generation (and other choice dimensions) responsive to multimodal micro-scale accessibility measures – induced and suppressed demand
  - Accounting for behavioral heterogeneity in population (choice set determination, alternative decision structures, unobserved factors)
  - Accommodation of simultaneity in choice processes – some choices made jointly as a bundle
  - Enhanced representation of car ownership and usage by type, vintage, and fuel technology
  - Demographic and vehicle fleet evolution models
Heterogeneity in Planning Contexts

Florida considerably diverse in terms of geography, sizes of metro areas, level of multimodal presence, and policy issues of importance

How can one size fit all?

- Some areas may not need a continuous time model
- Some areas may not be interested in a vehicle type choice and usage model
- Other areas may not be interested in explicitly modeling household member interactions

Current FSUTMS context accommodates variations across areas

- Provides a common foundational knowledge-base and infrastructure
- Individual areas can refine model system by implementing custom specifications, adding special modules, or simplifying components
Florida Standards for Activity Based Modeling

- May consider different model structures by planning context, metro area size, or level of multimodal presence

- Identify two or three model structures that would meet the needs of all planning contexts in state

- However, strive for consistency in foundational elements
  - Microsimulation approach (synthetic population generation, output individual activity-travel records for each person)
  - Treatment of time (resolution/fidelity)
  - Treatment of space (resolution/fidelity)
  - Computation of accessibility measures
  - Defining terms – chains, tours, stops, journeys, and trips
  - Accounting for simulation variation across multiple model runs
  - Menu based on choice dimensions of interest – required, desirable, optional – for example:
    - Destination Choice – required
    - Household interactions – desirable
    - Vehicle type choice and usage – optional

- Input databases and output databases/reports
Setting Up Infrastructure for Transition to Activity Based Modeling (2-5 years?)

- Data collection and assembly
- Establish database structures and software environments
- Methods to integrate ABM output with other travel components for assignment
- Demonstration projects in selected areas – compile experience and lessons learned
- Develop strategies for small areas (transferability studies; integration within larger regional model systems)
- Training and documentation
Five Pillars of ABM Design

- Sensitive to **policy issues** and planning applications of interest

- Based on sound **behavioral** theory/paradigm

- **Computationally** feasible and tractable
  - Model estimation
  - Model implementation

- Optimal use of available **data** (present and future)

- ABM should be both an **Activity**-Based Model and an **Agent**-Based Model
Thank You!
Congestion Pricing

**Toll strategies/pricing**
- Impose a toll and predict elasticity of demand (-0.1 to -0.4)

**Conventional models**
- Predict shifts in departure & arrival time
- Observed elasticity lower than predicted
- Why?
  - Joint activities
  - Latent demand
  - Value of time very different among segments
  - Entire activity-travel schedule modified by pricing

**Activity-based models could address these issues**
- Predict who reacts to policy at the individual level
- Predict activity scheduling and task allocation changes within households
HOV/HOT Lanes

- Conventional models
  - HOV as a mode (time and cost)
  - Overestimate the number of users
  - The problem is lack of accounting for intra-household interactions, constraints, and carpool formation

- Activity-based models
  - Include household member interactions
  - Include model/routine for car assignment to person
Parking

- Conventional models
  - Parking duration not modeled
  - Parking lot = destination of trip
  - Summary demand by period of day

- Activity based models
  - Explicit estimation of parking duration
  - Operate at fine temporal resolutions
  - Can keep track of cars in households

Note: More inventory data needed!
Transit Fare

Conventional models
- Zone to zone base fares
- Examine changes in ridership and correlate with fare changes

Activity based models
- Transit paths can be developed
- The impact of waiting times and costs examined in terms of overall change in scheduling
- Too much work? Should we calibrate this to potential for change?
Shorter Days and Weeks

- **Conventional models**
  - Not sensitive to work duration
  - Impose change in trip generation and see what happens

- **Activity-based models**
  - Activities, travel, and duration of activities are tied together
  - Changes in work duration and days of the week are explicitly modeled (increases in after work periods, available extra day to do other things and so forth)
Demographic Shifts

- **Conventional models**
  - Very few segments
  - Operate at OD level

- **Activity based models**
  - Operate at the individual and household levels
  - Include full-time vs. part time workers
  - Include children by age groups
  - Include many additional segmentations because of synthetic population generation
  - Key to this region’s ethnic diversity!
Car Ownership and Type

- **Conventional models**
  - Absent
  - Number of cars per household

- **Activity-based models**
  - Explicit car ownership and assignment to persons (identify primary driver)
  - Vehicle type choice can be incorporated (including body and fuel type)
Emissions Inventory

- **Conventional models**
  - Vehicle activity is handled by post-processing
  - Does not account for within household vehicle assignment and does not produce a vehicle trace → loss of vehicle use profiles

- **Activity-based models**
  - Details about who uses each vehicle and when/where
  - Some produce traces of vehicles during the day
  - New emissions models able to take advantage of such information
  - Beginning to explore linkages with dynamic traffic assignment
Land Use & Development

- **Conventional models**
  - Build scenarios and data input to 4-step model
  - Zone to zone travel time and costs (accessibility indicators) used in land use
  - Can be done in a feedback fashion for lagged effects over time

- **Activity based models**
  - Offer opportunity for true integration
  - Land use driven by location desires (and developer desires)
  - Travel models use more detailed land use data
  - Moving to parcel level, but many issues are not solved yet
CEMDAP – Objectives

- To allow for rapid implementation of system variants
- To accommodate possible future system expansions
- To deliver a transparent - as opposed to a “black-box” - modeling tool
- To perform simulation in realistic run-time
How MDCEV alters CEMDAP

For every household model activity participation using MDCEV Model

For each child not undertaking joint discretionary activity
- Decision to undertake independent discretionary activity (model GA16)

Decision of household to undertake grocery shopping (model GA17)
- Single adult household
  - No
    - Activity allocated to the single adult
  - Yes
    - Multiple adult household

For each adult
- Decision to undertake shopping given that household undertakes grocery shopping (model GA18)

For each adult
- Decision to undertake personal/household business activities (model GA19)

For each adult
- Decision to undertake social/recreational activities (model GA20)

For each adult
- Decision to undertake eat-out activities (model GA21)

For each adult
- Decision to undertake other serve-passenger activities (model GA22)
MDCEV Alternatives Generation

- 9 Out-of-home non-work activity types
  - Shopping
  - Maintenance
  - Social
  - Entertainment
  - Visit
  - Active Recreation
  - Eat out
  - Other
  - Work-related

  Joint activity allowed in the first eight activities
Vehicle Fleet + Primary Driver Model

- Joint estimation of the household vehicle fleet characteristics and identification of the primary driver for each of the vehicles

- Emphasis on primary driver assignment is important
  - household decisions of what body type and vintage of vehicles to own, and who the primary drivers would be for each vehicle, are not made independently
  - the assignment of a primary driver for each vehicle owned by a household can be used in SimAGENT to assign a vehicle to each trip made by the household
  - the primary driver allocation → central behavioral consideration to produce more accurate travel and emissions forecasts in activity based models
CEMDAP – Software Architecture

Input Database → ODBC → Data Coordinator → Application Driver

Data Queries

Run-Time Data Objects:
- Household
- Person
- Zone Data
- Zone to Zone
- LOS Data

Simulation Coordinator

Modeling Modules:
- Decision to Work Model
- Work Start/End Time model

Output Files
CEMDAP’s Modeling Framework

- Two major steps:
  - Generation Allocation
  - Scheduling
CEMDAP: Simulation Outputs

- CEMDAP produces complete activity-travel patterns for a day for every individual in the population of interest

- There are seven output files:
  - **Adults**: decisions to undertake activities of different types for adults
  - **Children**: decisions to undertake activities of different types for children
  - **Workers**: pattern-level attributes of the workers’ (including adult students)
  - **Students**: pattern-level attributes of the child students
  - **Non-workers**: pattern-level attributes of non-workers
  - **Tours**: tour-level attributes
  - **Stops**: stop-level attributes
### Vehicle Holdings and Use

<table>
<thead>
<tr>
<th>Vehicle Type/Vintage</th>
<th>Makes/Models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coupe Old</td>
<td>33</td>
</tr>
<tr>
<td>Coupe</td>
<td>23</td>
</tr>
<tr>
<td>Sedan Mini/Subcompact Old</td>
<td>10</td>
</tr>
<tr>
<td>Sedan Mini/Subcompact New</td>
<td>7</td>
</tr>
<tr>
<td>Sedan Compact Old</td>
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<tr>
<td>Sedan Mid-size Old</td>
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<td>Sedan Large Old</td>
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<td>Sedan Large New</td>
<td>12</td>
</tr>
<tr>
<td>Hatchback/Station Wagon Old</td>
<td>23</td>
</tr>
<tr>
<td>Hatchback/Station Wagon New</td>
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<tr>
<td>SUV Old</td>
<td>15</td>
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<td>SUV New</td>
<td>23</td>
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<td>Pickup Truck Old</td>
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<tr>
<td>Pickup Truck New</td>
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<td>Minivan Old</td>
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<tr>
<td>Minivan New</td>
<td>15</td>
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<tr>
<td>Van Old</td>
<td>6</td>
</tr>
<tr>
<td>Van New</td>
<td>5</td>
</tr>
<tr>
<td>Non-motorized vehicles</td>
<td></td>
</tr>
</tbody>
</table>
Vehicle Fleet + Mileage Model

- MDCEV model provides aggregate forecasts of annual mileage of each of the vehicles in the household which is used by SimAGENT

- Aggregate mileage forecasts used as a quick-response tool
  - Examine the impact of a variety of land-use and transportation policies on GHG emissions and energy consumption
  - No need to run the complete SimAGENT system for each policy
Support from Texas Advanced Computing Center

- Free access to Linux based super computer, Ranger
- 11th fastest supercomputer in the world!
- 62,976 computer cores, 128 TB of aggregate memory, 1.73 PB of shared high speed storage
- Computer cluster configuration to run the activity based model
- Fast implementation of activity based travel demand model
- Can be used even after completion of project by SCAG
  - Currently using 50 nodes with 16 processors each, so a total of 800 processors.
  - 1 hour 40 minutes to run CEMDAP for 100% population
Toll Willingness to Pay

- Attitudes and willingness to pay for tolls on highways
- Develop behavioral equations of the willingness to pay
- Large scale regional simulation models to develop pricing strategies

(Bhat and Castellar, 2002; Bhat and Sardesai, 2006).
Mode Supplement

- Modes for active living studies.

- The survey objective is to identify situational constraints, attitudes, and predispositions in favor or against modes such as walk, bike and public transportation.

- Create models to study policy actions that go beyond the time cost-comfort analysis.

- Add a stated choice, intentions, and preference component to this module.

- Emphasis on collecting data about walking and biking either as a main mode for each trip or as an access mode to another main mode (e.g., walking from a parking lot to an office, biking to a bus top and then taking the bus).
Activity Satisfaction Survey

- Provide a benchmark for the diary instrument

- Create an assessment of activities (including trips) and subjective experiences that is able to capture preferences, satisfaction, and perceived quality of life

- This second set of objectives will enable estimation of choice models with latent variables and classes that are by far richer and more informative than their counterpart observed variable discrete choice models
We know that places have symbolic and other meanings that travel behavior models neglect.

This component identifies how destinations are perceived and what role these perceptions play in their selection.

Major aspects = mental maps and sense of place.
Panel of Households and Persons and Multi-Day Activity

- Undecided: would like a Mobidrive (6 weeks)
- Would also like year to year evolutionary measurement
- Most likely a rotating panel of longer than one week duration
Energy Use and Expenditures

- Link housing to transportation demand
- Develop more complete household Greenhouse footprints
- Develop models of comprehensive accounting of energy demand
  - Annual, monthly, or even weekly expenditures for activity participation, travel, and vehicles and housing units maintenance ownership and energy consumption are not collected in typical travel survey
  - This component will provide the data needed to enable a direct association between travel and at home energy consumption to eventually create models of the type in Fissore et al. (2011).
Behavioral Basis of ABM

- Decision hierarchies and choice processes
  - A variety of behavioral decision structures possible
  - Virtually all models assume a sequential decision structure similar to traditional four-step models for computational convenience

- Considerable evidence of simultaneity in behavioral choice mechanisms
  - Several choices made simultaneously as a lifestyle package
Behavioral Basis of ABM

- Examples of simultaneous choice packages
  - Residential location, vehicle ownership, mode to pre-planned activities (e.g., work)
  - Activity type, activity duration, and activity timing (scheduling)

- In sequential choice processes, more constrained choice generally precedes less constrained choice

- Behavioral heterogeneity
  - Differences in choice processes across market segments
  - Identify market segments both exogenously and endogenously (latent market segments)
Time-Space Interactions

Activities and travel distributed in time-space continuum
  • Recognize time-space constraints in mode choice (transitions), destination choice, and activity-type choice

Role of time-space accessibility
  • Critical to modeling activity generation processes
  • Ability to explicitly represent induced or suppressed demand
  • Incorporation of Hägerstrand’s prism concept
Time-Space Interactions

- Activity 1 (Fixed)
- Activity 2 (Fixed)
- Home Activity
- Activity at Location A
- Urban Space
- Time

Activity 1

Home Activity

Activity 1 (Fixed)

Activity 2

Activity 2 (Fixed)

A

Work

ν
Accessible area for the male head
Accessible area for the female head
Accessible area for the child
Activity Attributes

- Disaggregate activity purpose definition
  - Challenge traditional notion of mandatory and discretionary activities/trips
  - Movie, ball game, and child’s tennis lesson or soccer game often have spatial and/or temporal fixity
  - Characterize activities and trips by level of spatial and temporal fixity/constraints (besides purpose
    - Can be accomplished using concepts of time-space geography
    - Automated method to add attributes describing degrees of freedom according to set of spatial/temporal fixity criteria to activity records in data set
Central Role of Time Use

- **Notion of time is central to activity-based modeling**
  - Explicit modeling of activity durations (daily activity time allocation and individual episode duration)
  - Treat time as “continuous” and not as “discrete choice” blocks

- **Activity engagement is the focus of attention**
  - Travel patterns are inferred as an outcome of activity participation and time use decisions
  - Continuous treatment of time dimension allows explicit consideration of time constraints on human activities

- **Reconcile activity durations with network travel durations (feedback processes)**
**CEMSELTS Validation Work Flows (LA Region)**

### County-County Flows (2000 Census Data)

<table>
<thead>
<tr>
<th>County of Residence</th>
<th>Imperial</th>
<th>Los Angeles</th>
<th>Orange</th>
<th>Riverside</th>
<th>San Bernardino</th>
<th>Ventura</th>
<th>Total</th>
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<tbody>
<tr>
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### County-County Flows (CEMSELTS Work location module)

<table>
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<th>Imperial</th>
<th>Los Angeles</th>
<th>Orange</th>
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<tbody>
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### County-County Flows Error Matrix

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<th>Imperial</th>
<th>Los Angeles</th>
<th>Orange</th>
<th>Riverside</th>
<th>San Bernardino</th>
<th>Ventura</th>
<th>Total</th>
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<tr>
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<td>7.3</td>
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<td>Orange</td>
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<td>3.9</td>
<td>7.5</td>
<td>1.0</td>
<td>0.2</td>
<td>2.4</td>
</tr>
<tr>
<td>Riverside</td>
<td>0.3</td>
<td>0.9</td>
<td>3.8</td>
<td>15.6</td>
<td>5.9</td>
<td>0.1</td>
<td>1.0</td>
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<tr>
<td>San Bernardino</td>
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<td>2.1</td>
<td>0.9</td>
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<td>0.2</td>
<td>0.4</td>
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<tr>
<td>Ventura</td>
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<td>3.2</td>
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</table>
## Base Year Generation Validation: Household Level

### Housing Type for Renters

<table>
<thead>
<tr>
<th>Housing Type</th>
<th>Predicted</th>
<th>Census</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Family Detached</td>
<td>26.8</td>
<td>20.6</td>
</tr>
<tr>
<td>Single Family Attached</td>
<td>8.4</td>
<td>3.9</td>
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<tr>
<td>Multi-Family/Apartment/Condo</td>
<td>64.8</td>
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<td>Mobile Home/Trailer</td>
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### Vehicle Ownership

<table>
<thead>
<tr>
<th>Vehicle Ownership</th>
<th>Predicted</th>
<th>Census</th>
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<tbody>
<tr>
<td>Zero Vehicles</td>
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<td>One Vehicle</td>
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<td>Two Vehicles</td>
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<tr>
<td>Four or more Vehicles</td>
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</table>
### CEMSELTS Validation Person Level (LA Region)

<table>
<thead>
<tr>
<th>Educational Attainment (18 yrs &amp; above)</th>
<th>CEMSELTS</th>
<th>ACS 2003</th>
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</thead>
<tbody>
<tr>
<td>High school or less</td>
<td>70.4</td>
<td>69.6</td>
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<tr>
<td>Associate</td>
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<td>Bachelors</td>
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<table>
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<td>42.9</td>
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<tr>
<td>Employed</td>
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<td>Total error</td>
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</table>

<table>
<thead>
<tr>
<th>Employment Industry</th>
<th>CEMSELTS</th>
<th>ACS 2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction and Manufacturing</td>
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<td>20.7</td>
</tr>
<tr>
<td>Wholesale Trade and Transportation</td>
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<tr>
<td>Professional, Personal, and Financial</td>
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<tr>
<td>Public and Military</td>
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<tr>
<td>Retail and Repair</td>
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</table>
## CEMSELTS Validation Household Level (LA Region)

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<tr>
<th></th>
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<tbody>
<tr>
<td><strong>Number of workers</strong></td>
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<tr>
<td>Households with no worker</td>
<td>16.8</td>
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<td>Households with 1 worker</td>
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<td>Households with 3 or more workers</td>
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<tr>
<td>Total error</td>
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</tr>
<tr>
<td><strong>Number of vehicles</strong></td>
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<td></td>
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<tr>
<td>Households with no vehicles</td>
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<td>8.3</td>
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<tr>
<td>Households with 1 vehicle</td>
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<td>Households with 2 vehicles</td>
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<td>Total error</td>
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### Residential Tenure

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### Housing Type for Owners

<table>
<thead>
<tr>
<th></th>
<th>CEMSELTS</th>
<th>ACS 2003</th>
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<tbody>
<tr>
<td>Single Family Detached</td>
<td>93.8</td>
<td>88.1</td>
</tr>
<tr>
<td>Single Family Attached</td>
<td>3.2</td>
<td></td>
</tr>
<tr>
<td>Mobile Home/Trailer</td>
<td>3.0</td>
<td>5.2</td>
</tr>
<tr>
<td>Multi-Family/Apartment/Condo</td>
<td>0.0</td>
<td>6.7</td>
</tr>
<tr>
<td>Total error</td>
<td>5.9</td>
<td>-</td>
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</table>

### Housing Type for Renters

<table>
<thead>
<tr>
<th></th>
<th>CEMSELTS</th>
<th>ACS 2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Family Detached</td>
<td>30.5</td>
<td>27.9</td>
</tr>
<tr>
<td>Single Family Attached</td>
<td>8.4</td>
<td></td>
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<tr>
<td>Mobile Home/Trailer</td>
<td>0</td>
<td>1.4</td>
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<tr>
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## CEMDAP Validation: Trip Generation (LA)

<table>
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<tr>
<th>County</th>
<th>Imperial</th>
<th>Los Angeles</th>
<th>Orange</th>
<th>Riverside</th>
<th>San Bernardino</th>
<th>Ventura</th>
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<tbody>
<tr>
<td><strong>Trip Purpose</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
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<td>5888380</td>
<td>2773915</td>
<td>55452207</td>
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<table>
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<th>Los Angeles</th>
<th>Orange</th>
<th>Riverside</th>
<th>San Bernardino</th>
<th>Ventura</th>
<th>Total</th>
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<tbody>
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<td></td>
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## CEMDAP Validation: Mode Shares

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<th>San Bernardino</th>
<th>Ventura</th>
<th>Total</th>
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<tbody>
<tr>
<td>Drive Alone</td>
<td>39.0%</td>
<td>37.9%</td>
<td>39.5%</td>
<td>41.3%</td>
<td>40.1%</td>
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<td>39.1%</td>
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<tr>
<td>Shared Ride (as driver)</td>
<td>22.6%</td>
<td>22.4%</td>
<td>22.6%</td>
<td>22.1%</td>
<td>22.4%</td>
<td>22.0%</td>
<td>22.4%</td>
</tr>
<tr>
<td>Shared ride (as passenger)</td>
<td>28.5%</td>
<td>28.4%</td>
<td>27.9%</td>
<td>27.6%</td>
<td>28.2%</td>
<td>27.8%</td>
<td>28.2%</td>
</tr>
<tr>
<td>Transit</td>
<td>0.0%</td>
<td>1.4%</td>
<td>1.1%</td>
<td>.3%</td>
<td>.4%</td>
<td>.7%</td>
<td>1.0%</td>
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<tr>
<td>School Bus</td>
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<td>1.1%</td>
<td>1.0%</td>
<td>1.3%</td>
<td>1.4%</td>
<td>1.1%</td>
<td>1.1%</td>
</tr>
<tr>
<td>Non-motorized</td>
<td>8.4%</td>
<td>8.7%</td>
<td>7.9%</td>
<td>7.3%</td>
<td>7.6%</td>
<td>7.7%</td>
<td>8.2%</td>
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<table>
<thead>
<tr>
<th></th>
<th>Imperial</th>
<th>Los Angeles</th>
<th>Orange</th>
<th>Riverside</th>
<th>San Bernardino</th>
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<tbody>
<tr>
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<td>39.91%</td>
<td>45.98%</td>
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<tr>
<td>Shared Ride (as driver)</td>
<td>21.16%</td>
<td>20.02%</td>
<td>18.44%</td>
<td>20.73%</td>
<td>21.34%</td>
<td>18.41%</td>
<td>19.86%</td>
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<td>Shared ride (as passenger)</td>
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<td>24.06%</td>
<td>22.56%</td>
<td>25.41%</td>
<td>25.97%</td>
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<td>24.00%</td>
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<td>11.43%</td>
<td>10.92%</td>
<td>11.87%</td>
<td>11.71%</td>
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</table>
Episode Start Time Distribution

% of Episodes

Sample
Simulated

Time of Day

3 AM - 4 AM
5 AM - 6 AM
7 AM - 8 AM
9 AM - 10 AM
11 AM - 12 PM
1 PM - 2 PM
3 PM - 4 PM
5 PM - 6 PM
7 PM - 8 PM
9 PM - 10 PM
11 PM - 12 AM
1 AM - 2 AM
Work Start Time Distribution

% of Work Starts

Time of Day

- 3 AM - 4 AM
- 5 AM - 6 AM
- 7 AM - 8 AM
- 9 AM - 10 AM
- 11 AM - 12 PM
- 1 PM - 2 PM
- 3 PM - 4 PM
- 5 PM - 6 PM
- 7 PM - 8 PM
- 9 PM - 10 PM
- 11 PM - 12 AM
- 1 AM - 2 AM

Sample
Simulated
Distribution of the Number of Daily Home-Based Work Trips

- **Survey**
- **CEMDAP**

<table>
<thead>
<tr>
<th>Number of Trips</th>
<th>Percentage of Adults</th>
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<tr>
<td>0</td>
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<tr>
<td>1</td>
<td>20%</td>
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<tr>
<td>2</td>
<td>40%</td>
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<tr>
<td>3+</td>
<td>10%</td>
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Distribution of out of home Episodes by Activity Type

<table>
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<th>Activity Type</th>
<th>Percentage share</th>
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<td>Miscellaneous</td>
<td>35.00</td>
</tr>
<tr>
<td>Serve-Passenger</td>
<td>15.00</td>
</tr>
<tr>
<td>Eat-Out</td>
<td>10.00</td>
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<tr>
<td>Personal Business</td>
<td>10.00</td>
</tr>
<tr>
<td>Social/Recreational</td>
<td>5.00</td>
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<tr>
<td>Shopping</td>
<td>5.00</td>
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Sample vs. Simulated
## CEMDAP Validation: Trip Distribution

<table>
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<tr>
<th></th>
<th>Imperial</th>
<th>Los Angeles</th>
<th>Orange</th>
<th>Riverside</th>
<th>San Bernardino</th>
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# CEMSELTS Validation: Person Level (LA Region)

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<tbody>
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<td><strong>Educational Attainment (18 yrs &amp; above)</strong></td>
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<tr>
<td>High school or less</td>
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<td>Associate</td>
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<td>Bachelors</td>
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<tr>
<td>Wholesale Trade and Transportation</td>
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<tr>
<td>Professional, Personal, and Financial</td>
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</table>
Successfully ported to Linux supercomputer

Run Time

Steps:

- Copy the database to all the nodes. It takes about 25 minutes for copying the database to all nodes
- The run time after finishing the database copying is about 85 minutes
- Total run time on 50 nodes is 25+75 = 100 minutes

Also, as the number of nodes increases, the amount of time we have to wait in the queue to get access to the super computer also increases significantly

With 50 nodes, we should get the access to super computer within 2-3 hours and then should be able to run the entire population in another 1 hour 40 minutes