Activity-Based Modeling

Session 2: Institutional Issues for Managers

Speakers: John Gliebe and Rosella Picado

February 23, 2012
Acknowledgments

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# 2012 Activity-Based Modeling Webinar Series

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Learning Outcomes

• Typical motivations and concerns of agencies considering an activity-based model
• Familiarity with the evolution of activity-based models in the U.S.
• Development options for migrating from 4-step to activity-based models
• Resources needed to implement an activity-based model program
• Experience with stakeholder acceptance and use
Terminology

• Upfront model development
• Phased model development
• Transferred model development
Universal Transportation Modeling System (UTMS)

• Developed in 1950s
• “4-step process”
• Limited by data availability and computing power
• Primary applications were planning for highway capacity--emphasis on vehicle trips and flows
• Reliance on simplified trip-based approach
• Aggregate relationships
Trip-Based Models Today: Advanced UTMS

Transportation System

Level of Service Between Origins and Destinations

Land Use / Activity System

Trip (End) Generation

Trip Distribution

Mode Choice

Network Assignment

Travel times and costs
Modeling a “Day in the Life”…

HB Work

Non-HB

HB Shop

Non-HB

grocery store

in zone V
(shopping)

home
in zone X

work place
in zone Y
(work)

restaurant
in zone W
(lunch)

by auto

on foot

on foot

by auto

6:00 P.M.

5:00 P.M.

5:30 P.M.

6:30 P.M.

7:30 A.M.

8:00 A.M.

12:00 P.M.

12:10 P.M.

12:50 P.M.

1:00 P.M.

5:00 P.M.

by auto

home
in zone X

work place
in zone Y
(work)

restaurant
in zone W
(lunch)

Non-HB
Why activity-based models?

• Activity-based models provide more information than trip-based models

• Intuitive models of behavior
  – Consideration of individuals, not just groups of households
  – Tour concepts (how trips are actually organized and scheduled)
  – Spatial, temporal, modal consistency between trips in the same day
  – Motivation for travel in activity participation (substitution between travel and other means of meeting personal and household needs)
  – Interpersonal linkages and obligations
  – Effects of accessibility (urban form) on travel generation
  – Long-term and short-term decision perspectives represented
Why activity-based models?

- Policy questions related to willingness or ability to pay
  - Fuel prices, mileage taxes and other operating costs
  - Parking costs
    - duration-based fees, employer subsidies
  - Road pricing
    - Variable time-of-day tolls (congestion/time of day)
    - Area pricing
    - HOT/HOV lanes
  - Transit fare policies (individual discounts, monthly passes, etc.)
  - Environmental justice
    - Impacts on minority or disadvantaged populations
Why activity-based models?

• *Policies that involve coordination between individuals and time-sensitive scheduling constraints*

  – Demographic changes
    • Household size and composition
    • Planning to support aging populations

  – New commuting options
    • Telecommuting
    • Compressed work schedule
    • Carpool/shared-ride arrangements

  – Parking
    • Capacity constraints/restrictions
    • Park-and-ride lot utilization rates and supply
What is the right tool for the job?

Simpler models work best for simple, narrowly defined problems, e.g.

Highway Capacity Project $\rightarrow$ 4-Step Planning Model $\rightarrow$ Highway Performance

More sophisticated models are needed for more complex problems, e.g.

Congestion Pricing Policy $\rightarrow$ Activity-based Model $\rightarrow$ Traffic and Revenue from Tolling
What are the consequences of not using the “best tool for the job?”

• Credibility
  – For complex problems, the modeling system may not be appropriately sensitive and may produce counter-intuitive outputs
    … or it might produce the right aggregate response, but you have no way of knowing how individuals are affected
    … or have trouble explaining the results
  – Potential for legal challenges based on methodology
  – Perception that you may not be using the best tools available
    • What are they using in the neighboring state?
Uncertainties of Implementing Activity-Based Models

• Cost
  – Can it be developed affordably?
  – Can we afford to maintain it?

• Resources
  – Will it require special technical skills that are difficult to find in-house?
  – How long will it take to develop?
  – Will it have a negative impact on agency productivity (longer run times, more maintenance, diverted resources)?
Uncertainties of Implementing Activity-Based Models

• Data
  – Will it require additional data collection?
    • Household diary surveys
    • Detailed land use/parcel level data
    • Additional traffic counts, boardings, etc. for calibration and validation
    • Parking supply data
    • Socio-economic data
Uncertainties of Implementing Activity-Based Models

• Quality
  – Will it have the desired sensitivity to justify the investment?
  – Will the methods used in an activity-based model be accepted in tightly regulated modeling contexts:
    • EPA conformity, FTA New Starts, NEPA alternatives analysis, LRP?
    • Will the agency still need to maintain a separate trip-based model?
Uncertainties of Implementing Activity-Based Models

• User Experience
  – What is the learning curve?
  – Will the application software be user friendly?
  – Will it be comprehensible and easy to explain to stakeholders?
  – Can the detailed output of an activity-based model be transformed into transparent and concise decision-supporting formats?
  – Will constituent agencies and consultants be able to use it?
    • Transit agencies, DOT partners, municipalities, local consultants
Activity Modeling Systems in the U.S.
Shift in Travel Modeling Paradigm

• 35 largest MPOs (1 million +) in US:
  – 17 of them have developed or are developing an activity-based model
  – All large-scale model development projects in the last 5 years were activity-based models

• State-wide strategic decisions to move to an activity-based model
  – Ohio
  – California
  – Florida
Implemented U.S. activity-based models

- San-Francisco County, CA (SFCTA) – in practice since 2001
- New York, NY (NYMTC) – in practice since 2002
- Columbus, OH (MORPC) – in practice since 2004
- Lake Tahoe, NV (TMPO) – in practice since 2006
- Sacramento, CA (SACOG) – in practice since 2008
- Oregon DOT – in practice since 2008
- Ohio DOT – in practice since 2009
- Atlanta, GA (ARC) – in practice since 2009
- San-Francisco Bay Area, CA (MTC) – in practice since 2010
- Denver, CO (DRCOG) – in practice since 2010
- Burlington, VT (CCMPO) – completed in 2011
- San-Diego, CA (SANDAG) – completed in 2011
Models currently under development in the U.S

- Seattle, WA (PSRC) – started in 2008
- Portland, OR (Metro) – started in 2008
- Los-Angeles, CA (SCAG) – started in 2009
- Phoenix, AZ (MAG) – started in 2009
- Chicago, IL (CMAP) – started in 2010
- Miami, FL (SERPM) – started in 2011
- Houston, TX (HGCOG) – started in 2011
- Jacksonville, FL (NFTPO) – started in 2011
- Tampa, FL (FDOT District 7) – started in 2011
- Philadelphia, PA (DVRPC) – started in 2012
Common Features of Activity-based Models

- Synthetic population generators
- Long-term, mobility models for work, school locations, auto availability
- Models that generate tours, sub-tours and stops on tours
- Models that choose destinations within a tour context
- Models that choose modes within a tour context
- Models that choose starting and ending times for tours and/or activities
- Simulation methods to generate outcomes
Tour Modeling Dimensions

- Tour primary destination
- Tour time-of-day
- Entire-tour mode
- Stop frequency
- Stop location
- Trip mode
- Trip departure time

Mode choice composite utilities (OD-accessibility)

Accessibility of potential activity sites along the route between the primary destination and home
Evolutionary Trends in Activity-Based Models

• Early fundamentals
  – Generation and scheduling of tours and daily activity patterns

• Adding spatial detail
  – Sub-zonal level land use detail to support analysis of land use and pedestrian accessibility (parcels, micro-zones)

• Adding inter-personal coordination
  – Intra-household activity generation and scheduling

• Adding temporal resolution and dynamics
  – More time slices, moving toward pseudo continuous time representation (better for modeling time-sensitive costs)
Activity-Based Modeling: Management Institutional

DaySim

INPUT DATA FILES
- Representative Population
- Parcel, Block or Microzone Data
- External Trips by Purpose
- Impedance Skim Matrices, by Period & Mode (from prior loop)

Mobility Choices (once per household)

Usual locations (once per worker or student)
- Work (Non-student workers)
- School (All students)
- Work (Student workers)
- Free Parking (Workers)

Usual travel methods (once per person)
- Schedule, mode and transit pass (Workers)
- Transit Pass (Non-workers)
- Auto Ownership (Household)

Travel Day Choices (once per household day)
- Household Day Pattern
  1. Choice of work, non-work or at-home day (modeled jointly for all persons in HH)
  2. Work and school tours (workers and students)
     a. tour and subtour generation
     b. half-tour travel coordination among workers and students
  3. Fully joint tour generation and participation
  4. Individual tour pattern and stop purpose generation

Tours (once per tour)
- Destination, Mode and Schedule
  Disaggregate tour logs (mode and schedule)
  Aggregate tour logs (destination, mode and schedule)

Intermediate stops and trips (once per stop within each half tour)
- Generate stop & purpose
- Activity Location
- Activity Schedule and Trip Mode

OUTPUT DATA
- Household (one record per HH day)
- Person (one record per person day)
- Tour (one record per person tour)
- Trip (one record per person trip)
- Joint travel (one record per joint tour, joint-half tour, partial-half tour)

CT-RAMP

1. Population Synthesis

2. Long-term
   2.1. Usual workplace / school

3. Mobility
   3.1. Free Parking Eligibility
   3.2. Car ownership
   3.3. Transponder Ownership

4. Daily & Tour Level
   4.1. Person pattern type & Joint Tour Indicator
     - Mandatory
     - Non-mandatory
     Home
     Available time budget
     Residual time
     Individual Mandatory Tours
       4.2.1. Frequency
       4.2.2. TOD
       4.2.3. Mode
     Joint Non-Mandatory Tours
       4.3.1. Frequency
       4.3.2. Participation
       4.3.3. Destination
       4.3.4. TOD
       4.3.5. Mode
     Individual Discretionary Tours
       4.4.1. Frequency
       4.4.2. Destination
       4.4.3. TOD
       4.4.4. Mode

5. Stop level
   5.2. Stop purpose
   5.3. Stop location
   5.4. Stop departure

6. Trip level
   6.1. Trip mode
   6.2. Auto parking
   6.3. Assignment
Similarities to Trip-Based Models

• Network assignment algorithms, skims and software
  – But perhaps more assignment time periods

• Socio-economic and land use inputs
  – But perhaps at more disaggregate spatial units

• Auxiliary travel markets:
  – Trucks and other commercial vehicle movements
  – Airport and visitor trips
  – IE/EI/EE trips
Transitioning to a More Advanced Modeling Tool

• Can one innovate incrementally?
• Are there methods that can add sensitivity to trip-based models to make them on par with activity-based models?
  – Additional market segmentation
  – TDM assumptions
  – 4D land use tool
• A more complicated trip-based model may not be worth the effort
• Adding features and segments to an existing trip-based model may become unwieldy
Historical Approaches to Developing Activity-Based Models

• Upfront development
  – Single concerted effort, one RFP
  – Multi-stage effort, intermediate deliverables, multiple RFPs

• Phased development
  – Multi-stage effort, replace 4-step model components gradually, multiple RFPs

• Transfer and refine
  – Single or multi-stage effort to adapt an existing model to a new region
Upfront Development – One RFP

Examples: New York (NYBPM), Columbus (MORPC), San Francisco (SFCTA), Denver (DRCOG)

• Advantages
  – Control over system design
  – Full system available
  – Cover all markets

• Disadvantages
  – New software
  – Entire budget must be committed upfront
Upfront Development – multiple RFPs

Examples: Atlanta (ARC), Sacramento (SACOG), Phoenix (MAG)

• Advantages
  – Control over system design
  – Effort can be scaled to available funding stream

• Disadvantages
  – Additional effort to select contractors
  – Risk that effort may be put on hold if funding is not available
  – Waiting time until full model features are available
Phased Development

Examples: San Diego (SANDAG), Seattle (PSRC)

• Advantages
  – Delay some costs until budget available
  – Resource development (data)
  – Gain familiarity with model software and operation
  – Control over system design

• Disadvantages
  – Not able to enjoy full benefits of model design until entire model is implemented
Transfer and Refine

Examples: Lake Tahoe (TMPO), Chicago (CMAP), Jacksonville (NFTPO), SF Bay Area (MTC)

• Advantages
  – Low cost solution to get started
  – Rapid implementation
  – Focus attention on key components
  – Proven to work elsewhere

• Disadvantages
  – Delay wholesale changes to model design to future
  – Unknown a priori whether the model will transfer well
  – Unknown effort required to refine the model to an acceptable level
  – Will likely need TBM longer
Questions and Answers
Resources Needed to Develop and Maintain Activity-Based Models

- Budget
- Development timeline
- Agency
- Software
- Hardware
- Data
- Funding mechanism
Development Cost Drivers

• Adopt existing paradigms or develop your own?
• Transfer of software of existing ABM or your own development?
• Full re-estimation of disaggregate models or adoption and aggregate recalibration?
• Include new, advanced features?
• Extent of data collection?
• Develop in-house or hire consultant?
How much did it cost?

• It can be difficult for agencies to separate out the costs of activity-based model development from other activities
  – Range of consulting budgets and staff FTEs – separation of budgets (before/after)
  – In-kind contributions of MPO staff
  – Database development (GIS, surveys) serve multiple purposes
  – Maintenance costs blended into work programs

• The first activity-based models started from scratch, but newer development options have different cost structures
Development Cost – Sacramento Example

• $849,000 in consulting fees over 11 years
  – Initial development costs $514,000 to get to calibrated model in 2008
  – 2011 Model enhancement costs $335,000
    • Enhanced temporal resolution
    • Tolling/pricing analysis capabilities
• SACOG staff prepared land use parcel database over 5 years, a significant effort shared with other agency staff
Development Cost – San Diego Example

• $1.2 million in consulting fees over 4 years
  – Approximately $300k per year
  – Significant software development (micro-zones)
  – Phase I models (long-term models, tour\stop generation)
  – Phase 4 (last) includes a series of sub-models including
    • Airport passenger simulation
    • Cross-border travel simulation
    • Special Events
    • Visitor Model
    • External Travel Model
  – SANDAG staff provided support in development of a land use database
Development Costs – Other Examples

• Lake Tahoe - $250k
  – Transferred Columbus model and calibrated to local data
  – Developed a special visitor simulation model

• Chicago Metropolitan Agency for Planning ($800k)
  – $300k for initial pricing demonstration model, based upon ARC model with pricing enhancements
  – $500k for advanced transit innovations
Development Timeline Drivers

• What is the annual funding stream?
• How soon is the model needed?
• Is new data collection required?
• Build upon existing models, or develop your own?
• Include special market models?
• What will be the extent of agency staff involvement?
Development Timelines – Sacramento (SACOG)

Model Design 2001
Develop Parcel Database 2002-2004
Model Estimation 2005-2006
Model Calibration 2006-2008
Peer Review 2008
Model Update 2011
Development Timelines – San Diego Example

- **Model Design, Long-Term Models, and Phase I Model**: 2009
- **Tour Scheduling, Destination, Mode Choice Models**: 2010
- **Trip Models, Calibration**: 2011
- **Model Validation, Submodel Development, System Integration**: 2012
Agency Staff Resources

• Staff participation in model development depends on interest, skills, availability

• Ability to use the model effectively once it is implemented hinges on being able to understand it and explain it. This means investing in building staff activity-based modeling skills.

• Direct involvement in model development helps reduce budget for consultant services, and increases familiarity with model system
Agency Staff Resources

• San Diego Example
  – Approximately 2-3 FTEs on the development and maintenance of the activity-based model
  – This is 30% of their transport modeling staff time
  – Some support required from land-use modeling staff

• Sacramento Example
  – Approximately 3-4 FTEs on the development of the parcel database in 2004
  – 4 staff working ½ time and 3 staff working ¼ time on modeling activities (2 ¾ FTE total)
Model Maintenance and Applications Support

• Prepare input data, operate the model, analyze model results
• In-house GIS, database and SQL programming skills essential
• In-house programming skills highly desirable
• Consultant assistance for model extensions and upgrades
Software

• All models rely on commercial transportation planning packages for skimming and assignment (TransCAD, Cube, EMME, VISUM)

• Models deployed or under development are written in object-oriented languages (C, C++, C#, Java); some are open source, public domain software

• Data management and data query software are required to maintain input and output datasets and create reports and visualizations (MS SQL, MySQL, etc.)

• Some models use distributed computing architecture (JPPF, Windows HPC)
Hardware Specification and Cost

• Most important driver of run time is the size of the model population
• Number of network assignment periods and feedback loops is also important
• Tradeoff between run time and hardware cost – more and faster processors reduce run time, but increase server costs
• Some models use distributed processing, splitting the computation time among several computers
• Other hardware includes backup systems and model run archiving capacity
Hardware Specification & Cost

• San Diego Example (CT-RAMP)
  – Trip-based model run time is 9-12 hours (with TransCAD) on a single desktop computer
  – Activity-based model run time is 12 hours with TransCAD on 24 processors (3 machines with 8 processors each - hardware cost $40,000)

• Sacramento Example (DaySim)
  – Trip-based model run time is 4-6 hours on a single desktop computer
  – Activity-based model run time is 16-20 hours with Cube on a single desktop computer, purchased in 2008.
Hardware Specification and Cost

• Fresno, CA (DaySim):
  – 288,862 households
  – 820,890 persons

• Trip-Based Model System
  – Total run time: 12 hours with 3 feedback loop iterations
  – “3-step demand components”: 2 hours per iteration
  – Running on 2.8GHz 8 core machine, 16GB of fast RAM

• Activity-Based Model System
  – Total run time: 8 hours with 3 feedback loop iterations
  – DaySim demand components: 1.3 hours per iteration
  – Running on 2.93GHz 4 core machine, 16GB of standard RAM
    (Cube Voyager used in both cases)
Data Requirements

• Data requirements are the same or similar to those of trip-based models

• Some optional model features call for additional data collection:
  – Parcel or micro-zone population and land use inventories
  – Parking availability, transponder ownership, transit pass ownership
  – Highway and transit operations data for multiple time periods
Data Requirements

• Recent household survey required for model estimation and development of some calibration targets
  – Activity based modeling is less forgiving of incomplete person roster, trip diaries or missing information
    • Requires consistency across trip choice dimensions and across individuals
  – But it can make use of data that is typically asked for but not used by trip-based models
    • Age, gender, occupation, employment status, driver license, usual workplace and school locations, vehicle used, etc.
Funding Approaches

• Build into model development work program
• External grants (SACOG, SANDAG)
• In-kind, cost-sharing arrangements
  – MPO staff develop land use database, networks, auxiliary demand (SANDAG)
  – MPO staff develop enterprise database, software (DRCOG)
• Cross-agency cost sharing
  – Two agencies share the cost of developing a common software component (ARC & MTC)
User Experience Compared with Trip-based Model

• Calibration, validation, sensitivity testing
• Model applications
• External users
• Communicating results to stakeholders
Calibration, Validation, Sensitivity Testing

• Calibration is similar to trip-based model.
• There are more models to calibrate, but they look better “off the box”.
• Validation to external sources (traffic counts, etc.) is nearly same as trip-based model
• Sensitivity testing is where activity-based models reveal their true advantages
  – Extremely important for staff comfort in adopting a new model
  – Comparison with legacy trip-based model is recommended
Model Applications

• SFCTA Applications
  – Congestion Management Program
  – Countywide Transportation Plan
  – Geary Corridor and Van Ness Avenue BRT Studies
  – Multiple Neighborhood Transportation Plans
  – Transbay Terminal Development
  – Caltrain Electrification Study
  – San Francisco Mobility Access and Pricing Study
  – Third Street Light Rail Study
  – MTA Central Subway New Starts Application
Model Applications

• NYMTC Example
  – Air Quality Conformity Reports
  – Regional Transportation Plan
  – Manhattan Area Pricing Study
  – Goethals Bridge Environmental Impact Study
  – Lincoln Tunnel Exclusive Bus Lane II
  – Evaluation of Tolls at the Henry Hudson Bridge and Rockaway Crossings
  – Highway development studies for the Tappan Zee Bridge, Gowanus Expressway, and Bruckner Sheridan Expressway
  – Long Island East Side Access Study (Commuter Rail)
  – Multiple subarea studies (highway & transit needs)
Model Applications

• SACOG Example
  – 2 Air Quality Conformity Reports since 2008
  – 2010 SB375 greenhouse gas (GHG) emissions analysis
  – 2008 head-to-head comparison with SACMET (trip-based model) in developing the 2035 Metropolitan Transportation Plan
  – Placer Vineyards transit-oriented development scenario analysis
  – Curtis Park Village infill development project scenario analysis
Model Applications

• Oregon Statewide Model
  – Oregon Bridge Study
  – Oregon Statewide Freight Plan
  – Willamette Valley Land Use and Transportation Visioning Study

• Ohio Statewide Model
  – Ohio Turnpike 2005 and 2010 toll changes.
  – US 22/36 Economic Impact Study.
  – Brent Spence Bridge Commodity Flow Study.
  – Go Ohio Transportation Futures.
  – TRAC program project evaluation.
External User Experience

• Municipalities, local consultants, transit agencies

• May be initial resistance to adopting a new tool
  – Lack of familiarity, skepticism
  – Concerns: hardware/software costs, productivity, staff abilities/training

• Keys to success are same as for internal staff
  – Training and documentation
  – User-friendly interface
External User Experience

• NYMTC
  – More than 30 external users among partner agencies and consultants

• SANDAG
  – Provides remote access to its servers

• ARC
  – Cloud computing implementation for external users
Stakeholder Acceptance and Use

• Disaggregate nature of activity-based models provides unprecedented opportunities for data exploration and derivation of performance measures

• Theoretical design of activity-based models (tours, scheduling, etc.) is closer to reality than trip-based abstractions

• Experience in communicating with stakeholders
  – Anecdotal evidence (SACOG) suggests that stakeholders generally find the results easy to understand and intuitive
Atlanta Dashboard – ABMVIZ
Generates Tables, Reports, Charts, Maps and Animations
Atlanta Example – Time Use Analysis

Activity-Based Modeling: Management Institutional
Atlanta Example – Radar Chart
Comparing Difference Entities Across Multiple Measures
Ongoing Developments

- Multiple instances of model transfers, with adaptations
- Continuous improvement of existing designs
- Better processing technology improves run times
- Scenario management and visualization of outputs continue to improve
- Integration with dynamic traffic assignment under development
- Integration with urban land use models underway (already achieved with 2 statewide models)
Review: Learning Outcomes

- Typical motivations and concerns of agencies considering an activity-based model
- How activity-based models have evolved in the U.S.
- Development options for migrating from 4-step to activity-based models
- Resources needed to implement an activity-based model program
- Experience with stakeholder acceptance and use
Questions and Answers
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