Why One Size Doesn’t Fit All
Activity-Based vs Trip-Based Models and Everything In Between

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December 1, 2015
“All models are wrong, but some are useful.”

– George Box, famous statistician
Goals

• Inform – not persuade
  – Understand spectrum of model designs
  – Understand pros and cons of different designs for different issues

• Limited focus
  – Passenger demand model structures only
  – Trucks/freight also important!
  – Network / supply side models also important!
Agenda

• Spectrum of Model Designs
• Issues
  – Theoretical
  – Practical
  – Policy
• Final Thoughts
Spectrum of Model Designs
Spectrum of Model Designs

- Advanced Activity-Based
- Enhanced Activity-Based
- Standard Activity-Based
- Disaggregate Tour-Based
- Aggregate Tour-Based
- Hybrid Trip-/Tour-Based
- Advanced Trip-Based
- 4-Step
- 3-Step
Spectrum of Model Designs – *Examples*

- **3-Step**
  - Bowling Green, Jackson

- **4-Step**
  - Louisville, Little Rock, Memphis

- **Advanced Trip-Based**
  - Salt Lake City, Anchorage, TDOT

- **Hybrid Trip-/Tour-Based**
  - Knoxville, South Bend

- **Aggregate Tour-Based**
  - Sydney, Stockholm, Paris

- **Disaggregated Tour-Based**
  - Honolulu, National Long Distance

- **Standard Activity-Based**
  - Nashville, Tampa, Sacramento

- **Enhanced Activity-Based**
  - San Diego, Chicago

- **Advanced Activity-Based**
  - Portland
Spectrum of Model Designs – *Simplified Types*

- **4-Step**
  - Louisville, Little Rock, Memphis, etc.

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- **Activity-Based**

- **Traditional**

- **Hybrid**
Traditional Trip-Based

- Practical tools developed to support planning
  - First, interstates; then rail transit; then air quality, etc.
- Trips as basic unit of analysis
- All trips modeled as independent of each other
  - Even within each trip, generation independent of distribution, mode, etc.
- Simple statistical models with limited explanatory variables
- Matrix data structure
- Standard software, well established
- Fast
Activity-Based Models (ABMs)

• Born out of academic desire to address inconsistencies in traditional models
•Began to be adopted as useful for land use effects, walk/bike planning, time sensitive pricing/policies, equity analyses
• People as basic unit of analysis (synthetic pop)
• Discrete choice models with many variables
• Monte Carlo simulation
• Relational database
Types of ABMs

• Disaggregate Tour-based
  – ‘simplified’ activity-based models, but still use activity-based framework/approach

• Standard Activity-based
  – Person level day pattern planning

• Enhanced Activity-based
  – Intra-household interactions
  – Bike/Ped assignment; station-level transit amenities

• Advanced Activity-based
  – Dynamic re-scheduling of activities, etc.
Hybrids

• Mostly developed after activity-based, as an attempt to compromise between theoretical and practical concerns
• Discrete choice models like activity-based, but no Monte Carlo simulation
  – Mode choice often before destination choice
• Some use of persons; some use of trip matrices
• Not as common as traditional or activity-based
Types of Hybrids

• Advanced Trip-Based
  – Linkage of NHB to HB trips through sequencing of model components
  – Newest model design, growing quickly

• Hybrid Trip-/Tour-Based
  – Tour level distribution modeling

• Aggregate Tour-Based
  – Many level nested choice models
  – Complex matrix manipulations
  – More common outside the US
Theoretical Issues
Aggregation Bias

- If $f(x)$ is non-linear, then $f(\text{avg}(x)) \neq \text{avg}(f(x))$
  - Example: Consider the probability of transit use for
    - 100 households with an average of 2.2 cars per household
    - 5 households with no cars, 15 hh with one car, 50 hh with two cars, 20 hh with three cars, 5 hh with four cars, 5 hh with five

- Considerable aggregation bias in traditional
- Reduced, but some aggregation bias in hybrids
  - e.g., no bias in mode choice, but bias in departure time
- Very little aggregation bias in activity-based
Consistency within Trips

• In traditional models, downstream choices are consistent with upstream, but not vice versa
  – No consideration of destinations / modes in generation, etc.

• Hybrids & ABMs use accessibility variables to introduce consideration of downstream choices in upstream choices
  – Hybrids typically use fewer / simpler accessibility variables; ABMs use more / more complex accessibility variables, but still make some simplifications
Sensitivity to Land Use

- Urban design, area type, density, centrality, mixed uses, etc., affect trip generation, trip distribution, mode choice, total VMT, etc.
- Little/no sensitivity to urban design, etc., in traditional models
- Almost all hybrids and all activity-based models include more realistic sensitivity to land use
Spatial Consistency of Trips with Tours

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An example of a possible trip table from a gravity model with seven trips (H-a, H-c, a-H, a-c, b-b, b-c, c-c):

- There is no way that all seven of these trips can be arranged into one or more tours.
- Real travelers could not produce the travel pattern in this trip table, but a four-step model can!
- For instance, one traveler doesn’t return home!
Closed Tours

- An example of a possible trip table with identical row & column sums for seven trips (H-a, H-b, a-H, a-H, a-c, b-a, c-a):
  - These trips could be produced by either the tours
    - H-a-H & H-b-a-c-a-H
    - H-b-a-H & H-a-c-a-H

- Hybrid & ABMs ensure consistency with non-pathological tours by linking the choices of destinations of different (HB & NHB) trips
  - Hybrids choose HB stops (or stop locations) then NHB stops (or stop sequences), ensuring aggregate consistency
  - ABMs choose primary destination/stop, then add intermediate stops, building up individual tours one stop at a time
Modal Consistency of Trips within a Tour

- Generally travelers can’t drive if they didn’t take a car with them from home
  - If bus to work, can’t drive alone to/from lunch
Temporal Consistency of Trips within a Day

• Travelers can’t be in two places at once, timing of trips inter-related
• Traditional models have little/no understanding of time
• Hybrids are a little better, but not much
• ABMs generally required to ensure temporal relationships and consistency
Activity-Based

Distance from Home

Time Window

H – Home
D – Daycare
W – Work
L – Lunch
C – Coffee
G – Grocery

Time-of-Day

AM  Noon  PM  Evening
Hybrid

- Closed tours / spatial consistency
- Some inconsistencies in locations
- Tours can overlap in time and space
- Time windows not clear

Distance from Home

AM  Noon  PM  Evening

H – Home
D – Daycare
W – Work
L – Lunch
C – Coffee
G – Grocery
Traditional Trip-Based

- No consistency in time and space
- Little understanding of time

Distance from Home

Time-of-Day

H – Home
D – Daycare
W – Work
L – Lunch
C – Coffee
G – Grocery

AM | Noon | PM | Evening

D → W → H
D → L → W → L
H → W → G → H
H → H

Inter-Personal Consistency of Trips

• Two people can’t both drive one car
• If student is dropped off at school, adult has to make this stop (at the right school & time)
• Only enhanced ABMs begin to strictly enforce this type of consistency and even they still don’t enforce all types of inter-personal consistency
Spatial Resolution

• Traditional, most hybrids and even some ABMs use TAZs
• Most ABMs and a couple advanced trip-based use both TAZ and microzones (~ blocks)
• Microzones necessary for distribution / assignment of walk/bike trips and sensitivity to walk/bike infrastructure (sidewalks, bike lanes)
• Preparing microzone data, especially for the future, is burdensome
Integration of Big Data

- New sources of passive OD “Big Data” such as AirSage allow new data-driven forecasting
  - Increasing evidence data-driven methods more accurate
  - Data driven approach basis of FTA’s successful new STOPS transit forecasting tool
  - Required in UK and common outside US, growing within US
- Much easier to incorporate in traditional and hybrid models
- Chattanooga ABM one of the first attempts to incorporate Big Data in ABMs
DTA Integration

- Difficult to integrate traditional or hybrid models with DTA to allow dynamic re-scheduling, etc.
- Only advanced ABMs can achieve this
- Still somewhat theoretical concern since region-wide DTA is still computationally infeasible
- But may be a real practical concern in the future
Simulation Variation

• Because ABMs use Monte Carlo simulation with random draws, results can vary from run to run, particularly for small scale results, so multiple runs can be required

• Particularly challenging for traffic applications like traffic impact analysis and traffic signal coordination
Runtime

• Usually more a function of assignments than demand models, but still some differences
• Traditional models still fastest
• Hybrids still intermediate runtimes
• ABMs still longest, but not as long now as a few years ago due to software optimization
Calibration

• More complex models more difficult to calibrate both because of longer runtimes and because more ‘knobs’ to adjust – can lead to some question about whether correct parameter has been adjusted, especially in ABMs
Cost

• More complex models still tend to cost more than simpler models, largely because of calibration, but cost difference has decreased dramatically

• ABMs now only marginally more expensive than other options if developing whole new model

• However, hybrids can be developed by incrementally improving traditional models in several, smaller, less expensive steps
Software / Programming Languages

• Traditional and hybrids typically implemented completely in standard travel modeling packages using their scripting languages (TransCAD’s GISDK, CubeScript, etc.)
• ABMs almost all require two softwares & two languages (e.g., TransCAD/GISDK and Daysim/C#)
  – More staff skill/training required to be able to do in-depth analysis / “get under the hood”
User Communities

• User community (pool of potential staff, consultants, etc.) for traditional models still largest
• User community for ABMs quickly growing
• User community for hybrids small, but easier learning curve, especially for advanced trip-based models
Policy Issues
Traditional Highway Projects

• ABMs and Hybrids offer no advantage over Traditional models for new highways / added general purpose travel lanes
  – Although ABMs and Hybrids may do slightly better at forecasting volumes for lower class roadways
Transit Forecasting

- ABMs and Hybrids offer no advantage over Traditional models for new fixed guideway (rail) transit
- However, Hybrids / ABMs may allow better analysis of transit amenities (e.g., wifi onboard or at stops, branding)
- ABMs may be better able to model some transit related TDMs such as free transit passes for employees
Bicycle / Pedestrian Planning

• Traditional models struggle to represent walk / bike trips
• Hybrids do better, by considering walk/bike environment (walkability)
• Enhanced ABMs only models currently able to represent bicycle / pedestrian infrastructure enhancements
• However, this functionality could be added to Hybrids
Land Use Planning

• Traditional models are blind to urban design, mixed use developments, transit-oriented-developments, etc.

• Hybrids and ABMs can evaluate scenarios with different styles of development
  – Hybrids may be easier to use for this (require less inputs, no need for multiple runs)
Traffic Impacts

• Hybrid models can capture some degree of internal capture

• ABMs are less practical than either Hybrids or Traditional models because their simulation variation requires multiple runs to answer questions such as turning movement volumes
Emissions Analysis

• ABMs and Hybrids offer no advantage over Traditional models for conformity analysis

• ABMs and to some extent allow study of how much emissions / GHGs are produced by different neighborhoods, etc.
Equity Analysis (Demographic Resolution)

- Traditional and hybrid models can only summarize results / produce performance measures for a small number of market segments (e.g., HH w/ Autos, HH w/o Autos)
- ABMs produce results for individual travelers that can summarized any way desired
  - Equity analysis: impact on low income single parents
  - VMT/GHG per household
Highway Pricing

- Hybrids offer improvement over Traditional models because they can segment all travel (even NHB trips) based on whether it is on work tour (higher VOT) or not.
- ABMs theoretically offer best sensitivity for pricing analysis because of their better understanding of time windows, shared rides, etc.
  - ABMs better able to handle cordon pricing
  - Traditional models generally cannot consider time variable toll analysis
Peak Spreading

- Traditional models do not represent peak-spreading
- Hybrid models can represent peak-spreading but in a simplistic / statistical way
- Only ABMs explicitly represent time constraints which drive peak spreading behavior
Travel Demand Management

• Traditional models generally cannot evaluate travel demand management strategies
• Hybrids can provide some analysis, but ABMs are often required to investigate policies such as alternative work schedules, free transit passes for employees, etc.
Summary of Issues
# Theoretical Issues

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<th>Traditional</th>
<th>Hybrid</th>
<th>Activity-Based</th>
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<tr>
<td>Aggregation Bias</td>
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<td>Within Trip Consistency</td>
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## Practical Issues

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## Policy Issues

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Final Thoughts
What’s Important?

• Different issues are more important to different agencies
  – Traditional models hard to recommend, but
  – Agency with lots of traffic impacts, etc., may be suited with an advanced trip-based model
  – Agency with serious equity and time sensitive policy considerations may need ABM

• Some agencies maintain two models because of the pros and cons
My Top 5 Considerations

1. Accuracy vs. Sensitivity
   - Hybrid may be more accurate b/c big data
   - ABM offers best sensitivity for some issues

2. New Policies: Equity, Walk/Bike
   - How important are these issues?

3. Maintenance & Users
   - Staff maintain & apply model or consultants?
   - Staff willing & able to deal with 2 softwares/languages?

4. Commodity vs. Custom
   - Four-step and standard ABM are now ‘commodities’ vs. custom hybrid models

5. Runtime
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