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Why One Size Doesn't Fit All

Activity-Based vs Trip-Based Models and Everything In Between

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"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

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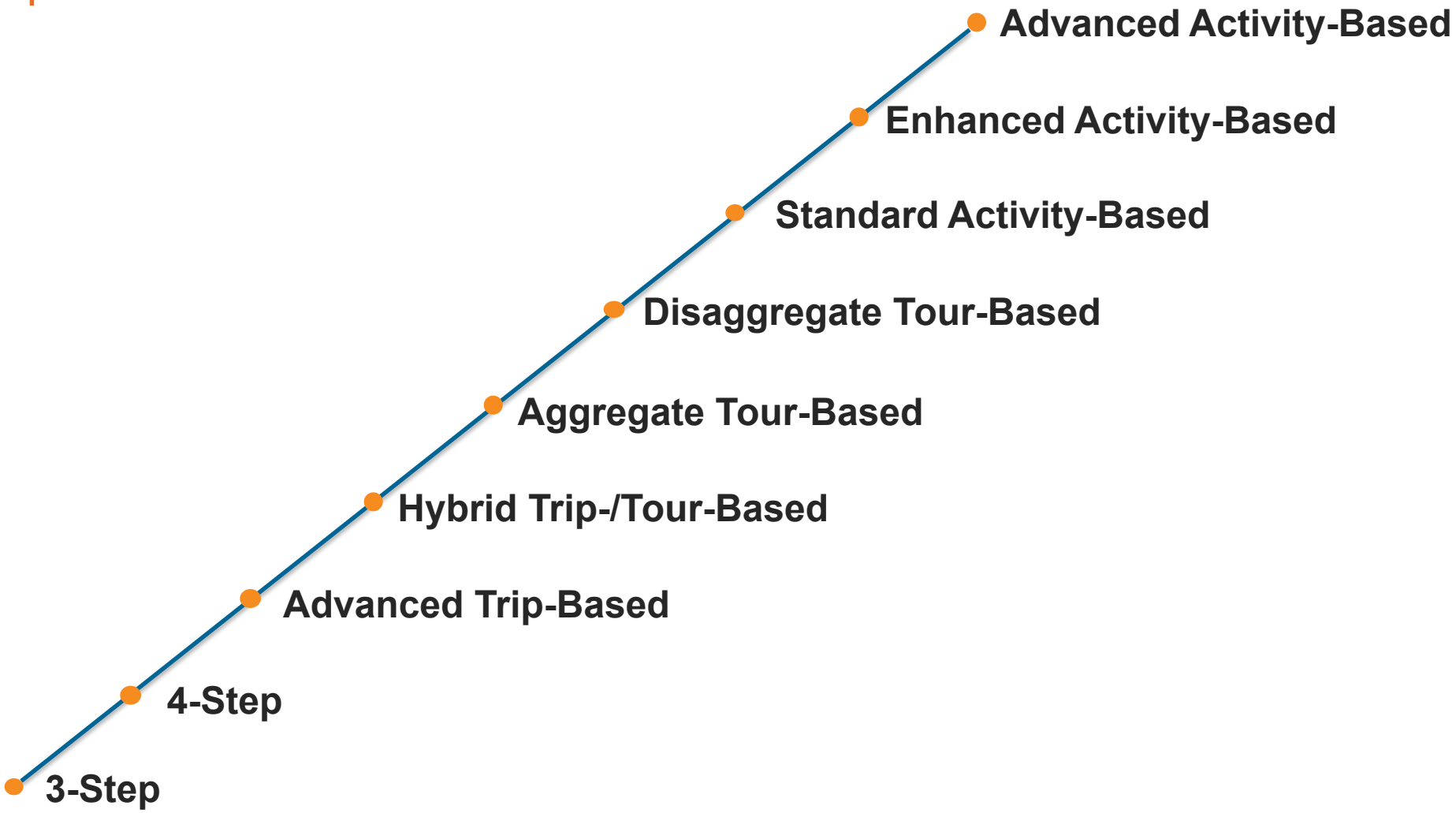


Spectrum of Model Designs – *Examples*

Spectrum of Model Designs – *Simplified Types*

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

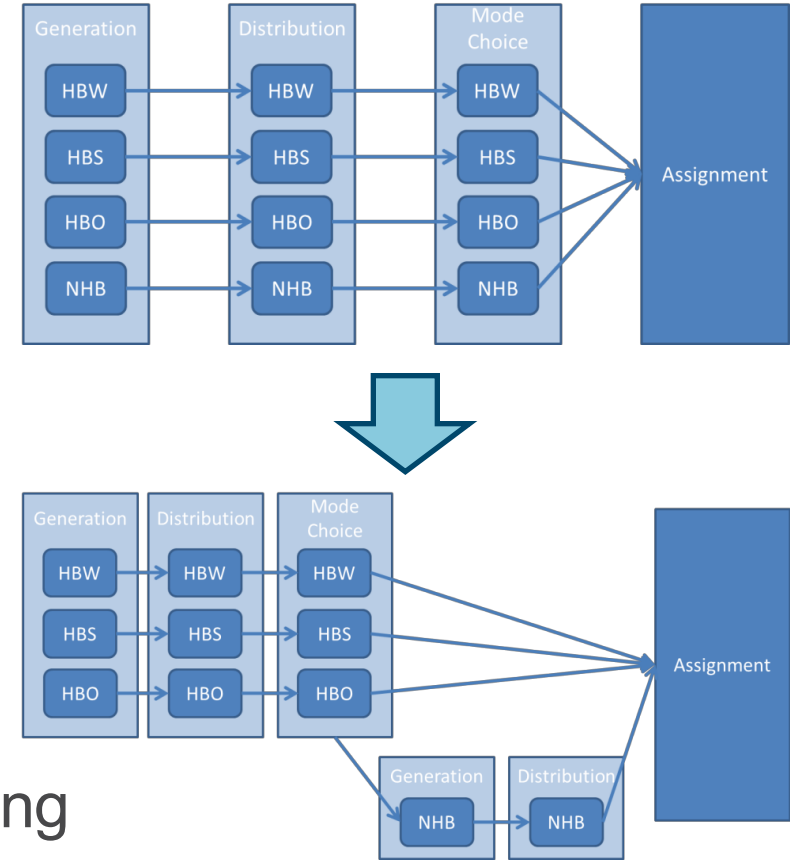
- Disaggregate Tour-based
  - 'simplified' activity-based models, but still use activity-based framework/approach
- Standard Activity-based
  - Person level day pattern planning
- Enhanced Activity-based
  - Intra-household interactions
  - Bike/Ped assignment; station-level transit amenities
- Advanced 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

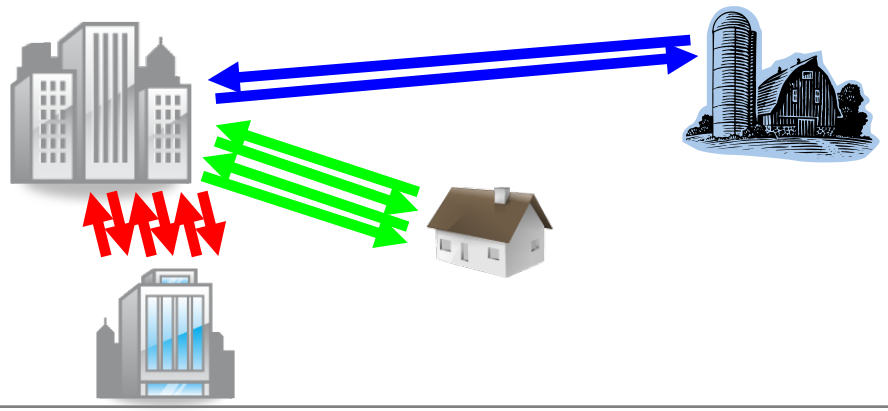
- If f(x) is non-linear, then f(avg(x)) ≠ avg(f(x))
  - Example: Consider the probability of transit use for
    - 100 households with an average of 2.2 cars per household
    - 5 households with no cars, 15 hh with one car, 50 hh with two cars, 20 hh with three cars, 5 hh with four cars, 5 hh with five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

- In traditional models, downstream choices are consistent with upstream, but not vice versa
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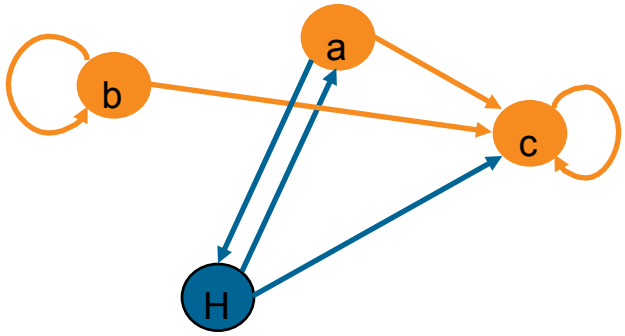
Open Tours

	H	a	b	c	
H	0	1	0	1	2
a	1	0	0	1	2
b	0	0	1	1	2
c	0	0	0	1	1
	1	1	1	4	7

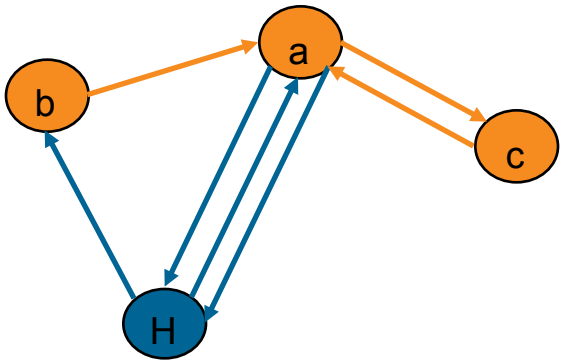


An example of a possible trip table from a gravity model with seven trips (H-a, H-c, a-H, a-c, b-b, b-c, c-c):

- 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**

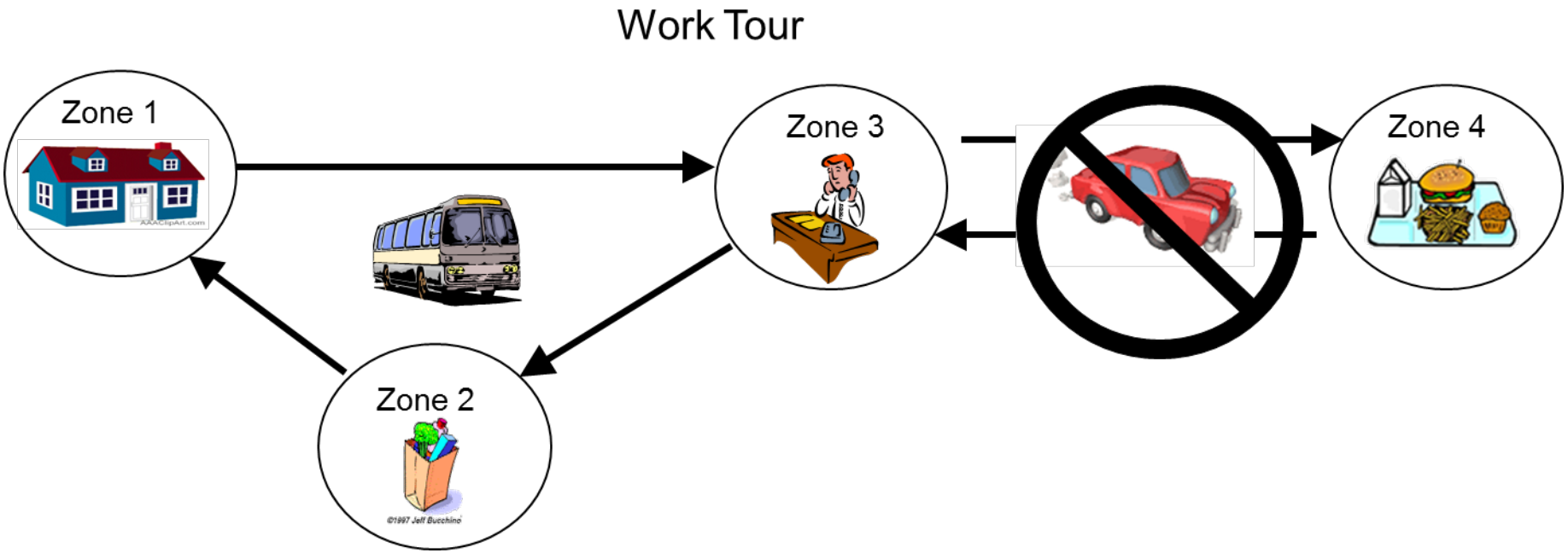


	H	a	b	c	
H	0	1	1	0	2
a	2	0	0	1	3
b	0	1	0	0	1
c	0	1	0	0	1
	2	3	1	1	7

- 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

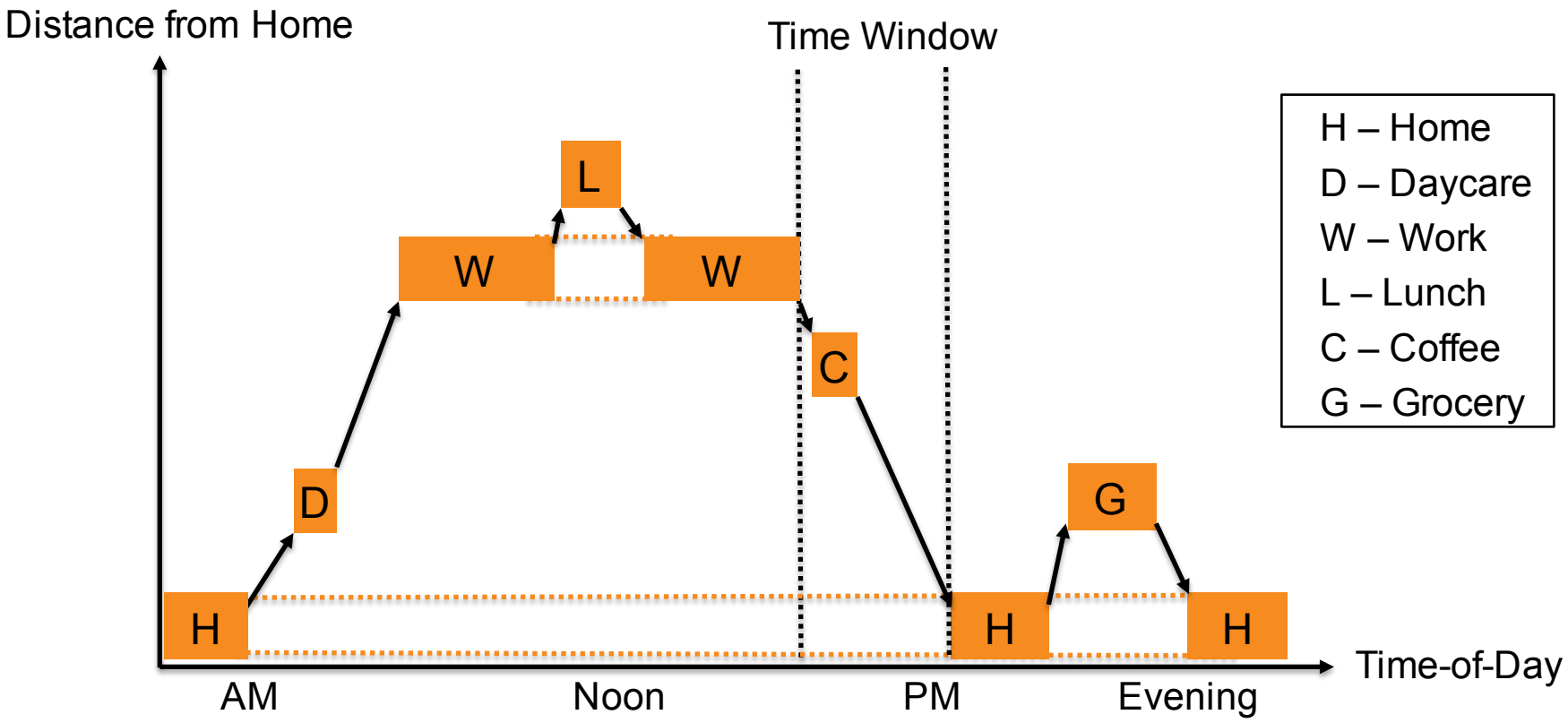
- Generally travelers can't drive if they didn't take a car with them from home
  - If bus to work, can't drive alone to/from lunch



Temporal Consistency of Trips within a Day

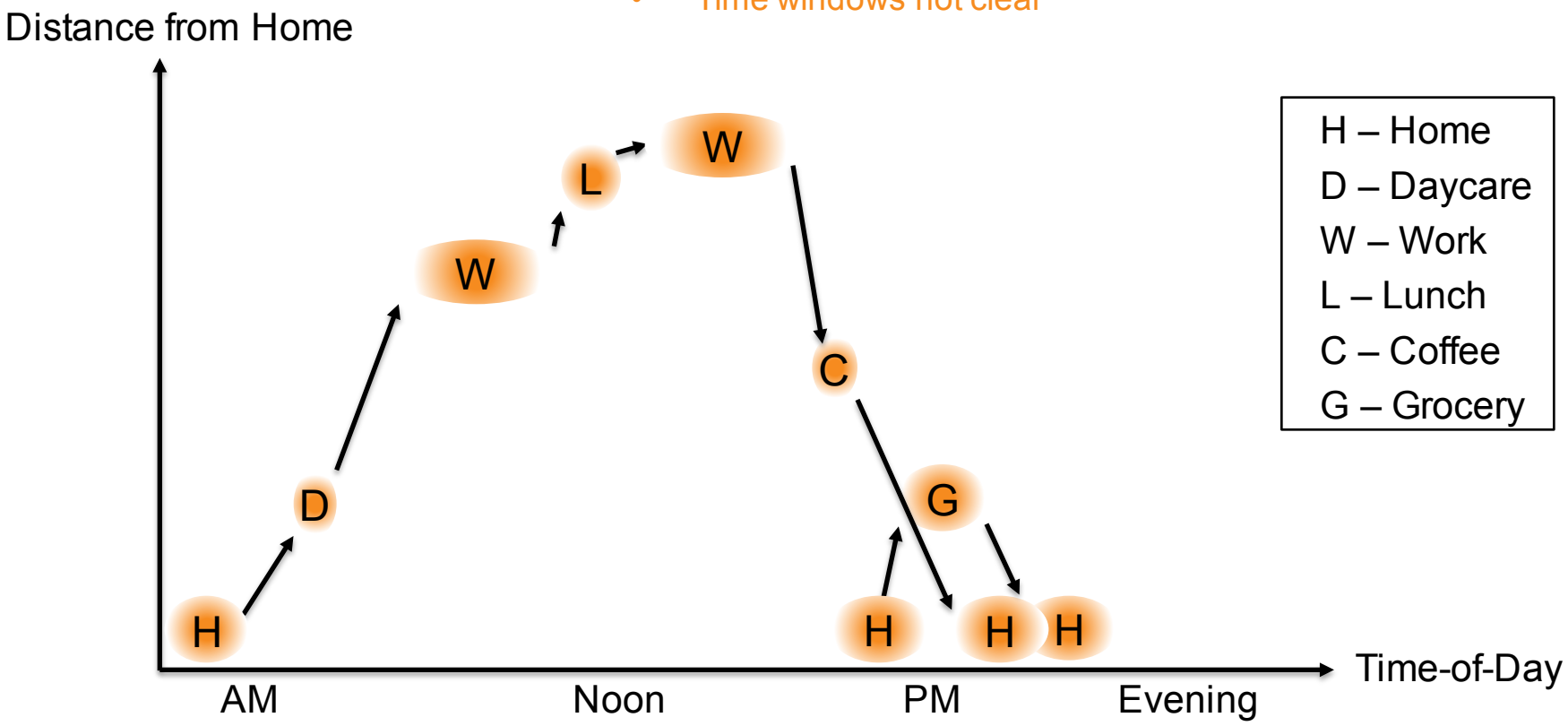
- Travelers can't be in two places at once, timing of trips inter-related
- Traditional models have little/no understanding of time
- Hybrids are a little better, but not much
- ABMs generally required to ensure temporal relationships and consistency

Activity-Based



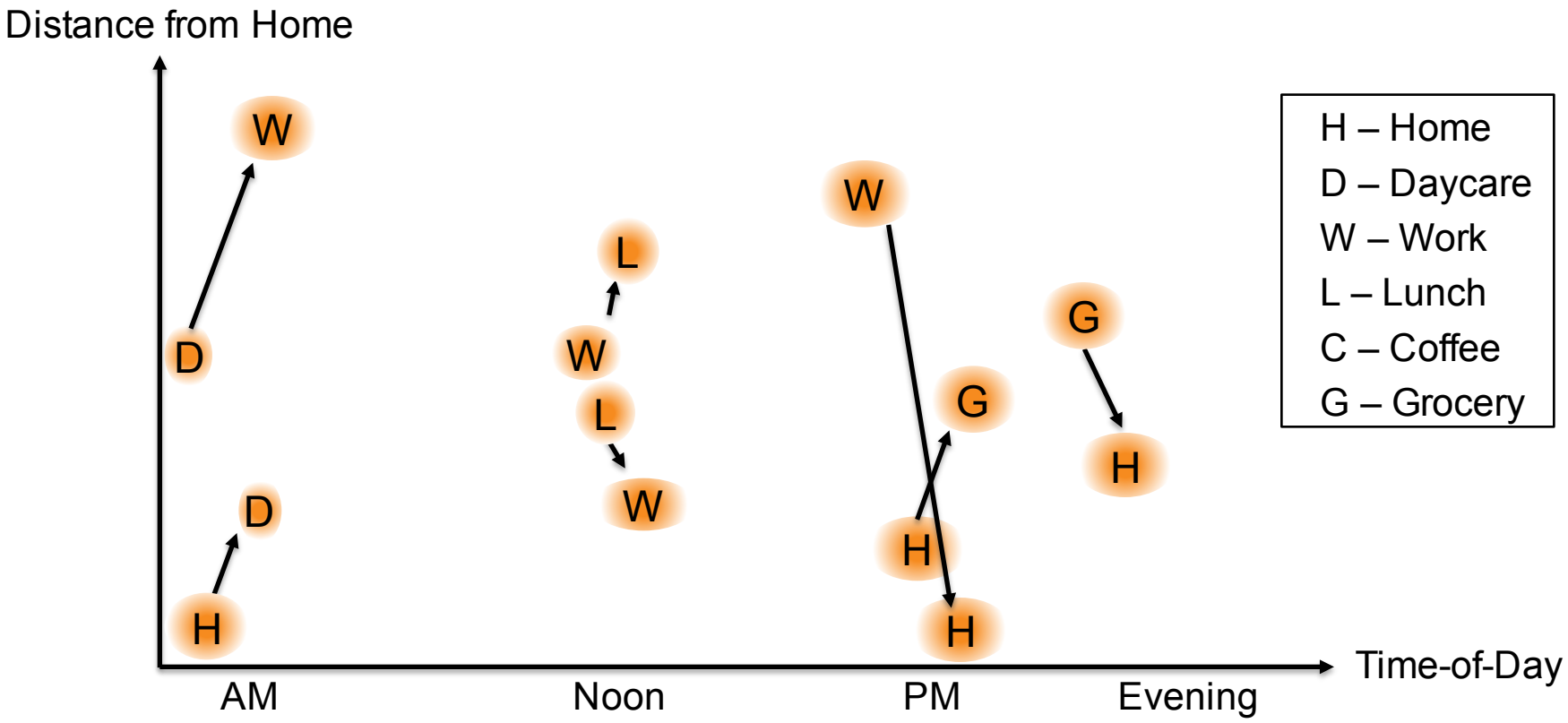
Hybrid

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



Traditional Trip-Based

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



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

Practical Issues

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

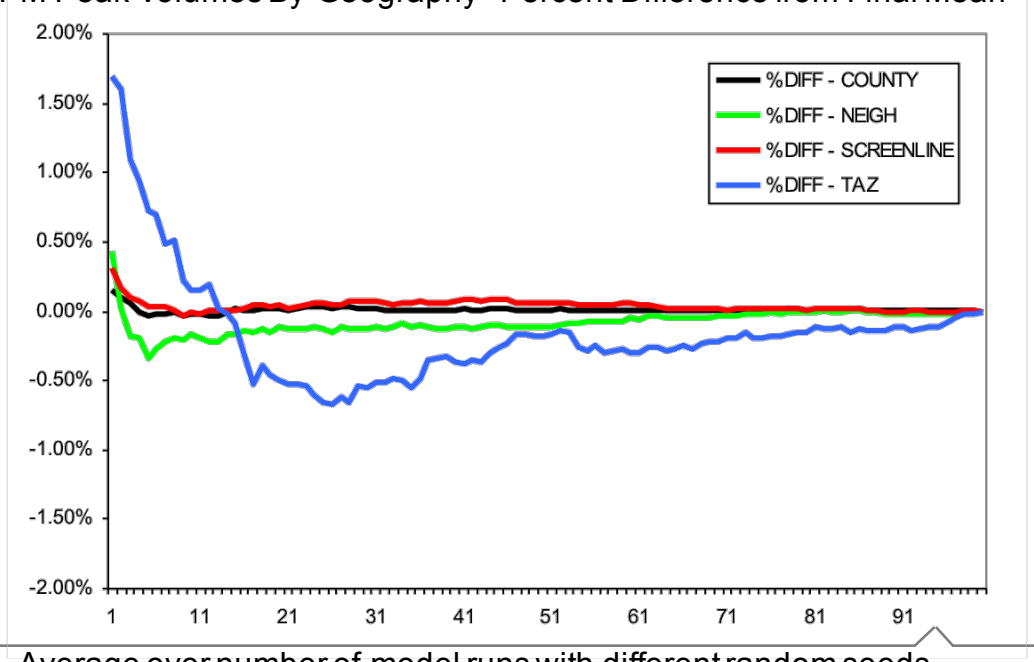
DTA Integration

- 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

PM Peak Volumes By Geography - Percent Difference from Final Mean



Average over number of model runs with different random seeds

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

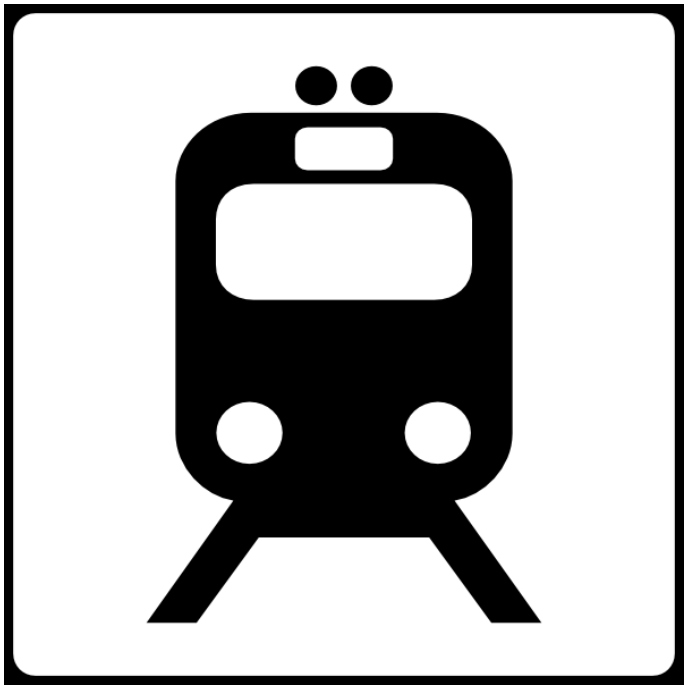
- User community (pool of potential staff, consultants, etc.) for traditional models still largest
- User community for ABMs quickly growing
- User community for hybrids small, but easier learning curve, especially for advanced trip-based models

Policy Issues

Traditional Highway Projects

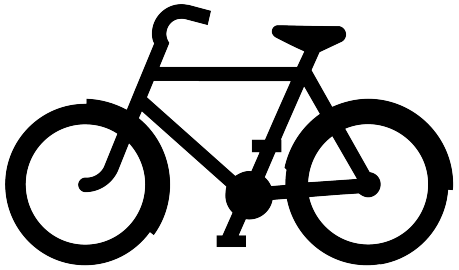
- ABMs and Hybrids offer no advantage over Traditional models for new highways / added general purpose travel lanes
  - Although ABMs and Hybrids may do slightly better at forecasting volumes for lower class roadways

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

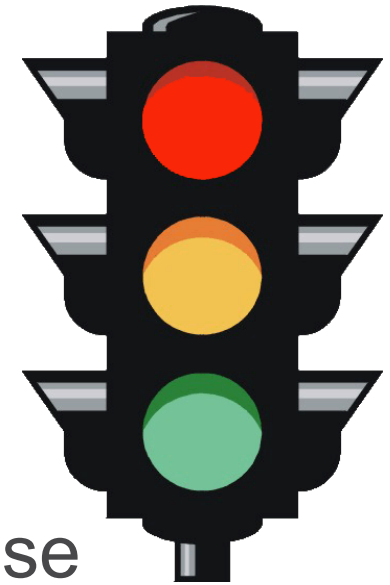


- Traditional models struggle to represent walk / bike trips
- Hybrids do better, by considering walk/bike environment (walkability)
- Enhanced ABMs only models currently able to represent bicycle / pedestrian infrastructure enhancements
- However, this functionality could be added to Hybrids

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



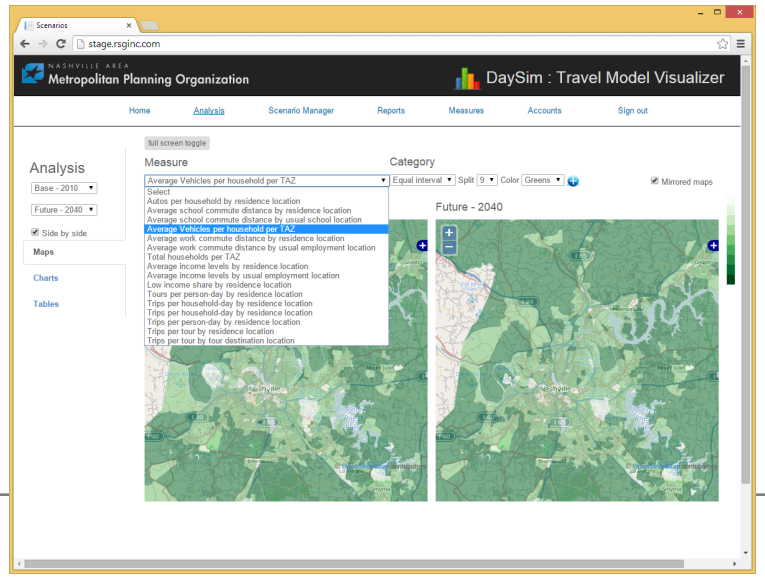
- Hybrid models can capture some degree of internal capture
- ABMs are less practical than either Hybrids or Traditional models because their simulation variation requires multiple runs to answer questions such as turning movement volumes

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

	Traditional	Hybrid	Activity-Based
Aggregation Bias	★	★★	★★★
Within Trip Consistency	★	★★½	★★★
Spatial Consistency of Trips with Tours	★	★★½	★★★
Modal Consistency of Trips in Tours	★	★★★	★★★
Temporal Consistency	★	★	★★★
Interpersonal Consistency	★	★	★★

Practical Issues

	Traditional	Hybrid	Activity-Based
Spatial Resolution	★	★	★★★
Big Data Integration	★★★	★★★	★
DTA Integration	★	★	★★★
Simulation Variation	★★★	★★★	★
Runtime	★★★	★★	★
Calibration	★★★	★★	★
Software / Programming Languages	★★★	★★★	★★
User Community	★★★	★	★★

Policy Issues

	Traditional	Hybrid	Activity-Based
Traditional highway projects	★★★	★★★	★★★
Major transit expansion projects	★★★	★★★	★★★
Bike/walk planning	★	★★	★★★
Land use planning – mixed-use, TODs	★	★★★	★★★
Traffic impact studies	★★	★★★	★
Air quality conformity / emissions	★★★	★★★	★★★
Equity analysis	★	★	★★★
Highway pricing studies	★	★★	★★★
Peak spreading	★	★★	★★★
Travel Demand Management	★	★★	★★★

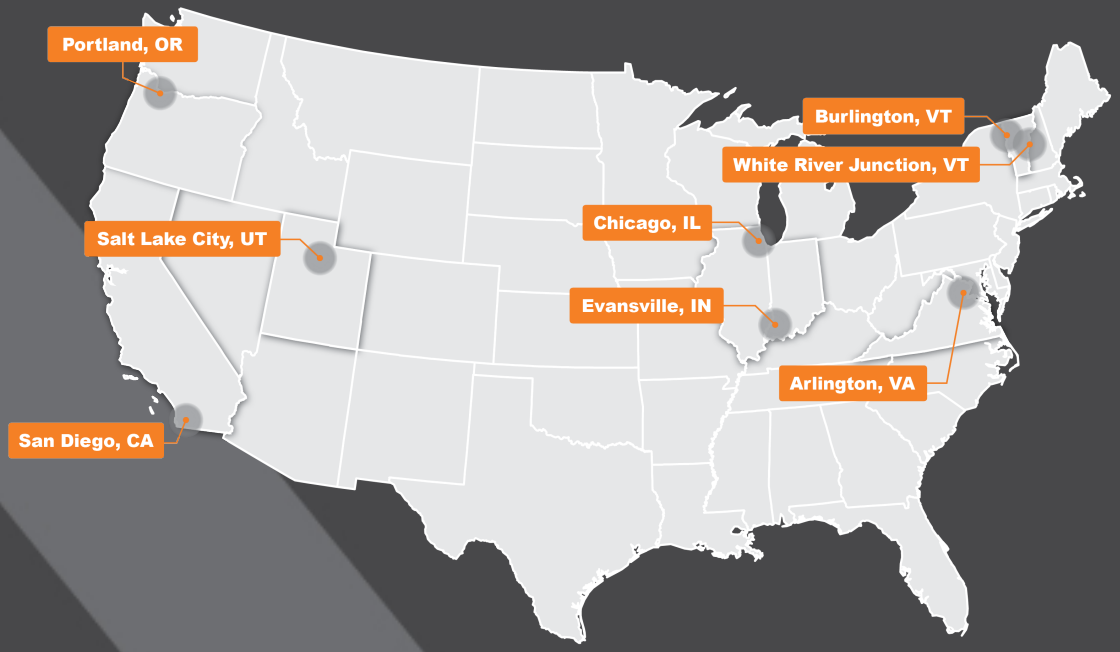
Final Thoughts

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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