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Dynamic Traffic Assignment and Mesoscopic Simulation with Cube Avenue

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SEFL FSUTMS User Group July 8 Meeting

Traffic Analysis Tools and Specialized Applications

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Transportation modelling tools

Macroscopic and Static Modelling

Mesoscopic and Dynamic Modelling

Microscopic and Dynamic Modelling

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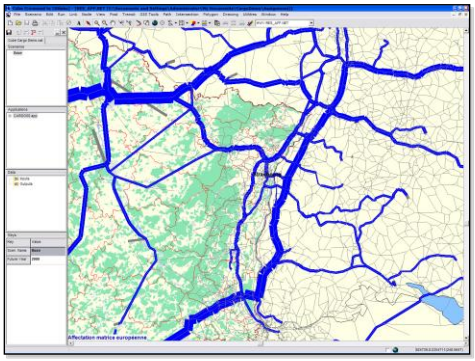
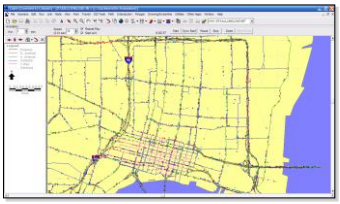
A Multi-Resolution Traffic Modeling Suite



Cube Voyager for regional flows



Cube Avenue for dynamic traffic assignment and bottleneck simulation

Cube Dynasim for corridor/subarea operations

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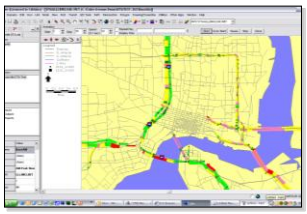
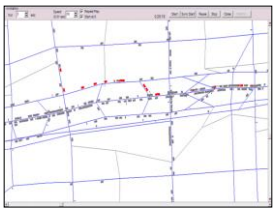
What is Cube Avenue?

- **Avenue is an optional add-on to Cube Voyager that enables *Dynamic Traffic Assignment* with *Mesoscopic Simulation*:**
  - ***Dynamic Traffic Assignment***
    Routes and flow rates change during the model period based upon congestion
  - ***Mesoscopic Simulation***
    Packets of vehicles are simulated as they move through the network
- **Easy to implement – because it uses the same data formats and scripting language as highway assignment in Cube Voyager**
- **Flexible – supports many of the same features e.g. multi-class, generalized cost...**





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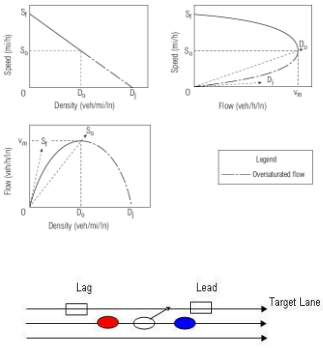
Congestion: the key to model scale

- ***Macroscopic*** **models evaluate congestion using speed-flow curves – based on fundamental traffic engineering relationships**
- ***Microscopic*** **models simulate individual vehicle trajectories on a detailed network and use behavior models (e.g. car following, gap acceptance) to predict second-by-second driver responses to en-route events**



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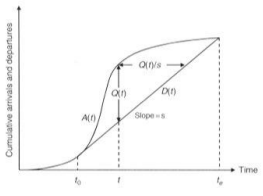
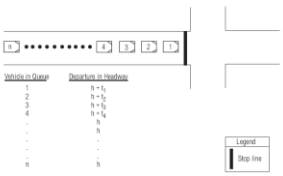
Mesoscopic Traffic Modelling

- **Typically** ***simulate*** **movement of trips along their routes at some detailed resolution (packet)**
- **Discretely model traffic** ***queues*** **in network at bottlenecks (e.g. intersections, ramps, tolls)**
- **Traffic** ***stream*** **performance is typically still evaluated using aggregate macroscopic (e.g. speed-flow) relationships**





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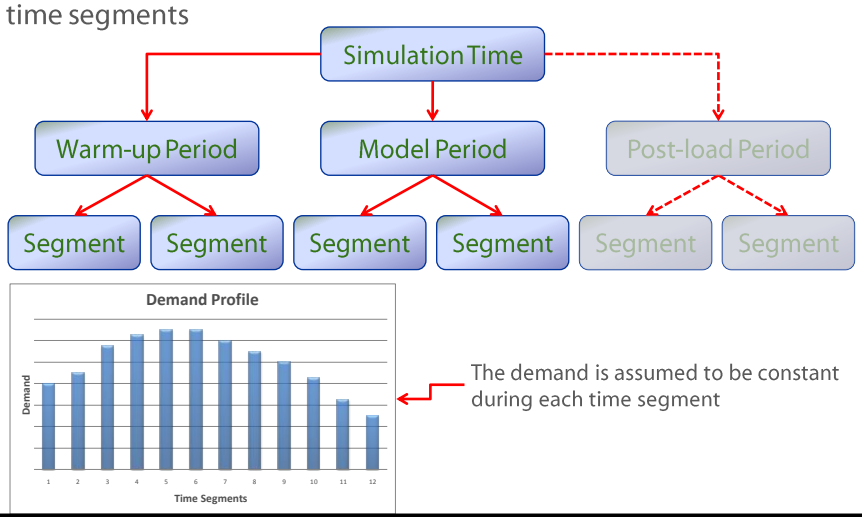
Cube Avenue – Dynamic Traffic Assignment (DTA)

- The model duration is explicitly defined and divided into smaller time segments



The demand is assumed to be constant during each time segment

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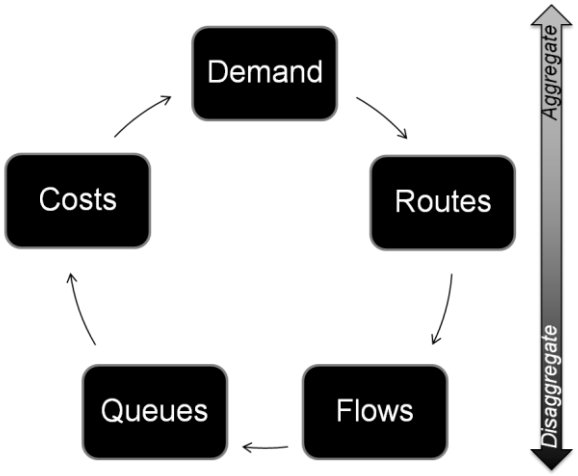
The temporal detail cycle



As Cube Avenue processes the various kinds of information used in dynamic traffic assignment, it moves between different levels of aggregation.

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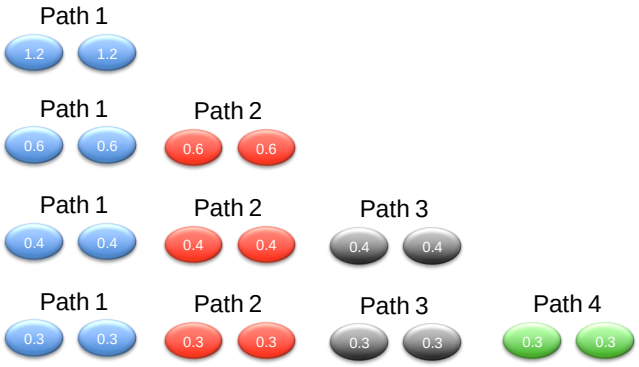
Method of Successive Averages



"Perfect" solution of MSA…
But maybe not practical… each iteration more packets…
Eventually you WILL run out of memory.

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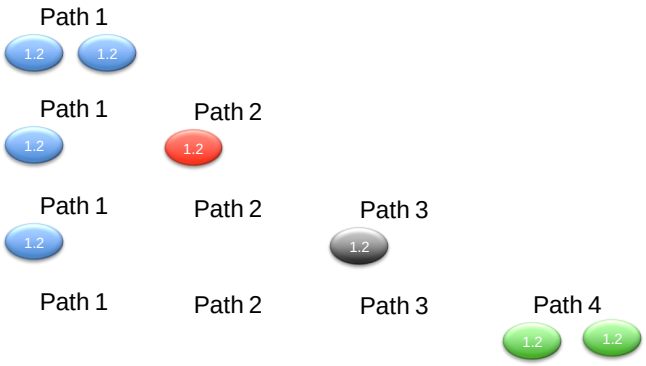
Packet Allocation Methodology



With each iteration, each packet has a MSA probability (1/Iter)
of being "Selected" for the fancy new path.
Globally the proper amount of trips are moved to the new path…
never runs out of memory or slows down.

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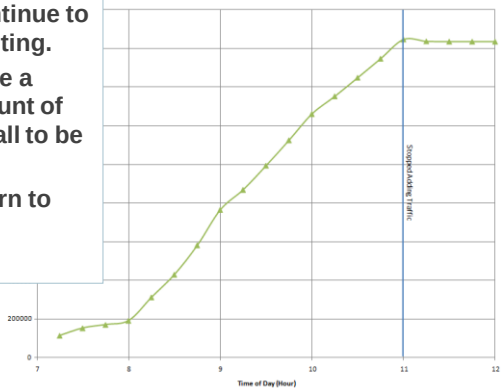
Loading in Congested Networks

- In extremely congested networks, an "All or Nothing" first iteration can cause gridlock.
- Later time segments have no hope of 'learning' how to navigate the network when earlier time segments continue to see drastic changes to their routing.
- When later iterations finally have a stable initial condition, the amount of traffic being adjusted is too small to be meaningful.
- A time segment must wait its turn to begin being assigned.



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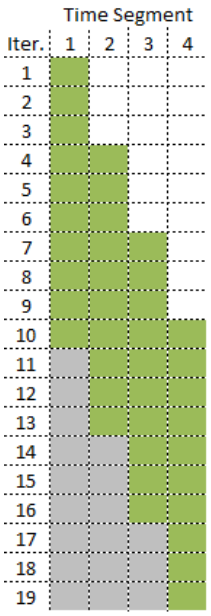
Incremental Time Segment Loading

- The user defines a number of iterations that each time segment gets to itself before the next time segment may start.
- Each time segment respects its own convergence and maximum number of iterations (maxiters)



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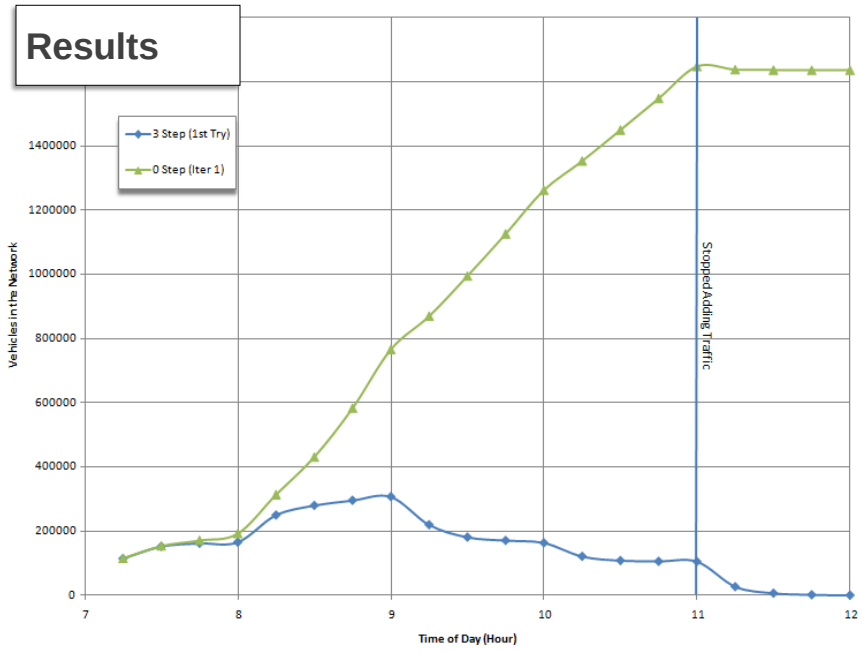
Results



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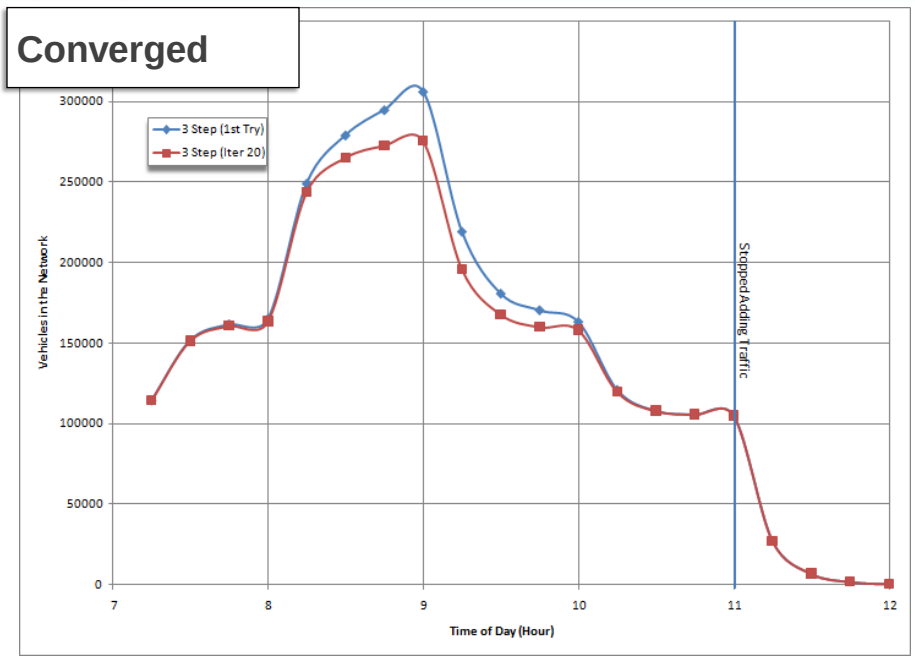
Converged



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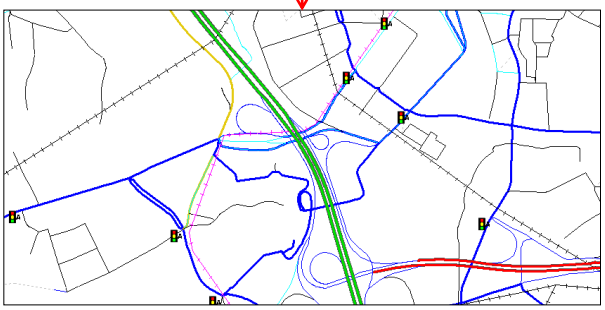
Cube Avenue – Input Data

- Time-varying O-D travel demand (flow per time segment)
- Link properties (Capacity, T0, Storage, Junction Modelling, ...)



Time Segment N

	D_1	D_i	D_z
O_1	$T_{1,1}$	$T_{1,i}$	$T_{1,z}$
O_i	$T_{i,1}$	$T_{i,i}$	$T_{i,z}$
O_z	$T_{z,1}$	$T_{z,i}$	$T_{z,z}$

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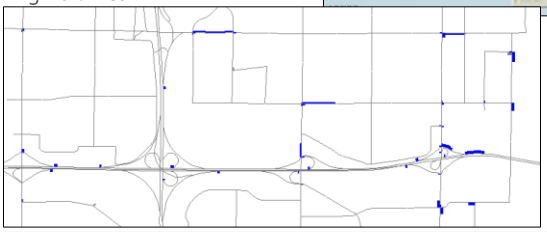
Cube Avenue – Output Data

- Dynamic bandwidth:
  - Flows
  - Queues
  - Vol/Cap ratio
  - ...
- Dynamic data at junctions:
  - LOS and delays
  - Queues
  - Turning volumes
  - ...



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Cube Avenue – Output Data

- Dynamic bandwidth:
  - Flows
  - Queues
  - Vol/Cap ratio
  - ...
- Dynamic data at junctions:
  - LOS and delays
  - Queues
  - Turning volumes
  - ...
- Packet animation

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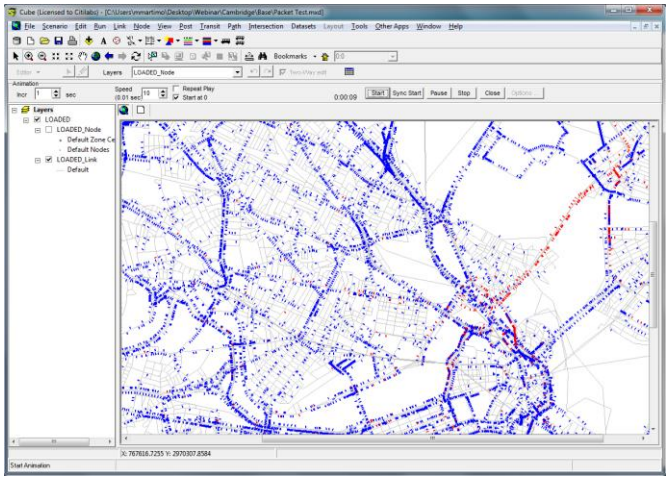
Packet Log Animations

- **Working closely with ESRI, we have now been able to add detailed animations to the GIS window.**



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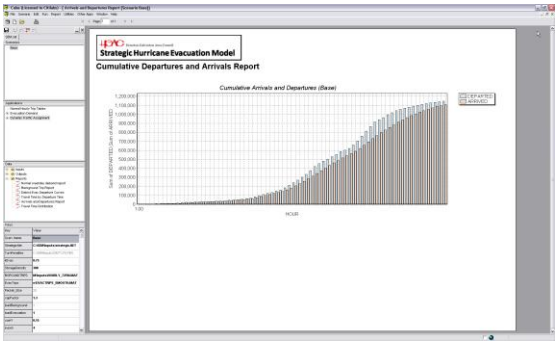
Reporting Simulated Arrivals and Departures



- **Cumulative departures and arrivals by hour**
- **Gap between curves indicates travel time > 1 hour (queueing)**
- **Slope of arrivals curve implies network throughput**
- **Graph shows only evacuation trips**

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Processing the Packet Log Data

By applying record processing techniques to packet log output data, you can implement many advanced analyses with Avenue:

- **Build origin-destination table from log file**
- **Select node/link analysis**
  - Select link/node trip table: build table of trips using some node at some particular time
  - Check whether packets used a particular link/node and build a link table from the list of nodes used by these packets (2 passes of the file)
- **Extract average queue for specific packets (departure minus arrival)**
- **Temporal disaggregation (e.g. build 15-minute matrices from peak hour simulation output based upon recorded departures)**
- **Peak spreading**
  - Build packet table from log file, flag packets that failed to arrive at their destination
  - Shift packets to new departure time segment based upon logit or other decision rule
  - Re-build hourly trip matrix from packet table
- **Other applications: ITS/VMS, parking, sub-area extraction, ME, etc…**

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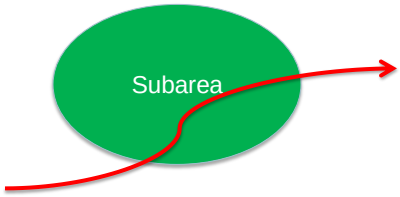
Hybrid Static/Dynamic Traffic Assignment

- **Example: sub-area analysis**
  - Identify trips whose paths traverse subarea and extract from table
  - Assign remainder statically, subarea trips dynamically
- **Addresses boundary problem**
  - Static subarea extraction process – Can't determine when the trip entered subarea
  - Dynamic subarea extraction process – Hybrid assignment
  - Realistic flow rates at the subarea boundary
  - Estimate of congestion from static and dynamic loads



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SERPM Highway Network

Subarea Highway Network

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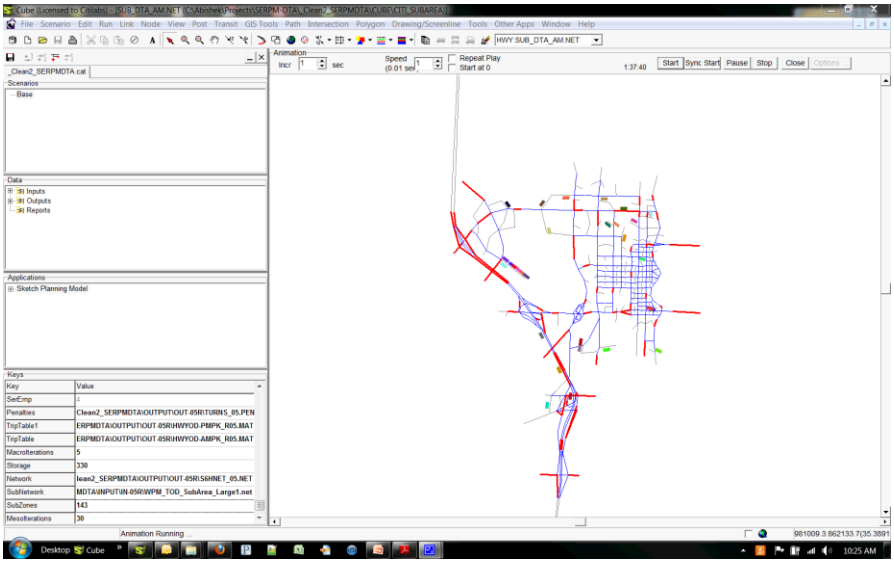
Animation in Cube Avenue



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Dynamic Origin-Destination Matrix Estimation

- **(Adjust) Subarea OD pattern ← Regional OD pattern**
  - Before passing through subarea simulation model
- **Cube Analyst: Limitations when working with Cube Avenue**
  - Cube Avenue builds true time-dependent shortest paths
  - Cube Analyst assumes route choice probabilities that are constant over time
  - Simulation enforces capacity constraints – Not necessarily balanced
- **Development of Dynamic OD Estimation process**
  - Mathematic Optimization method
  - Heuristic method

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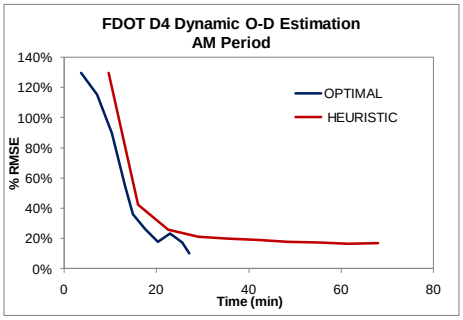
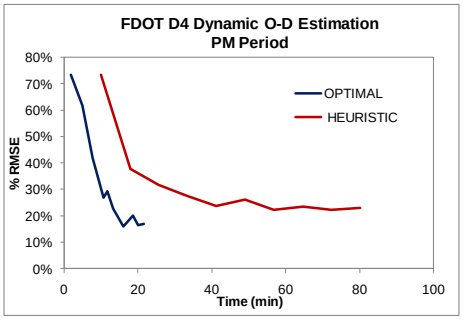
Convergence Results of O-D Estimation

- RMSE (%) by run time (min) for case without Cube Analyst run





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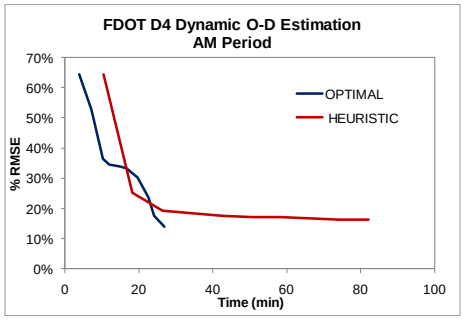
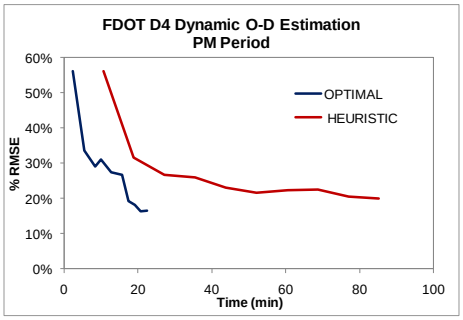
Convergence Results of O-D Estimation

- RMSE (%) by run time (min) for case with Cube Analyst run to adjust initial O-D trips





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Defining Project Scope for Avenue

- **Statement of purpose and need: why do we need DTA?**
  - More realistic highway traffic assignment
  - Animations & visualization of results
  - Simulation of traffic queueing
  - Special events / variable demand & supply
- **What products do we need or want the model to produce in order to satisfy this purpose?**
  - Turning movement flows
  - Queues at intersections
  - Dynamic maps
  - Link speeds by 15-minute interval

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Typical Cube Avenue Model Scales

- **Bottleneck or project simulation model**
  - Typical network scale: corridor / sub-area
  - Model period = AM or PM peak; Time segments = 5-15 minute intervals
  - Goal: model queuing at specific known bottlenecks
- **Average weekday time-of-day assignment**
  - Typical network scales: metro, county or city-wide
  - Model period = 24 hours; Time segments = 15-60 minute intervals
  - Goal: improve upon standard daily weekday assignment
- **Special event or evacuation model**
  - Typical network scales: statewide, metro, or county
  - Model period = 3-72 hours; Time segments = 30-60 minute intervals
  - Goal: model a specific disaster or system shock

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Data Needs and Checks for Cube Avenue

- **Origin-Destination Trip Tables by Time Segment**
  - Check to make sure that model period matches network capacity
  - Check (or calibrate) to ensure that the temporal and spatial distribution of demand is consistent with observed patterns (traffic counts)
- **Study area roadway network**
  - Make sure distances are accurate throughout (ideally GIS-based)
  - Check coded directional number of lanes & facility type throughout
- **Intersection definitions and turn penalties**
  - While helpful, it is *not* mandatory to include junction modeling; however check junction coding thoroughly if you are using them
  - Check hidden illogical turning movements that should be banned

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Capacity Assumptions

- **When calculating network capacity and flow/speed characteristics, we need to replace our planning assumptions with methods that are traditionally reserved for a more operational level of analysis; for example:**
  - Planning models commonly include capacity scaling factors in an attempt to show peak-hour congestion patterns within a peak-period or daily assignment. These should never be used in a DTA model; instead, multiply the hourly capacity by the number of hours in the model period to obtain the effective model period capacity.
  - Always think of CAPACITY and STORAGE as extreme or upper bound values, never use average conditions. For example, STORAGE only matters once a link is full of vehicles, so calculate based upon jam density (not moving+queued vehicles).

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Congestion Functions

- **Review the TC link congestion functions; consider changes**
  - Reasonableness checks; compare to literature
  - Compare to observed data (if available)
- **It may be helpful to differentiate functions by link class or use Akcelik equations.**
- **However, don't over-rely on the queuing model to tell the routing algorithm about congestion.**
- **For links with strange geometry or weaving and merging issues, it may be worthwhile to develop special curves via LOOKUP tables based on observed speed-flow data**

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Calibration & Validation Tips

- **Keep the project scope & goals in mind!**
- **Always check at least two of the three fundamental dimensions of traffic:**
  ***speed* (time),**
  ***flow* (volume), and**
  ***density* (queue)**
- **Use visualization tools to help e.g. bandwidth animation of multiple variables changing over time and space**
- **Never vary more than one variable or input at once**
- **Keep the script simple (though the capabilities are there)**

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Helping You to Create a Better Future