Introduction to Dynamic Traffic Assignment (DTA) and DTALite Open-Source Software

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Wi-Fi Information & Agenda

Wi-Fi account: transportationseminar Password: atryaschihua

9:00AM ~ 9:30AM	Welcome and introductions
9:30AM ~ 10:00AM	Module 1: Introduction to NEXTA/DTALite
10:00AM ~ 10:45AM	Module 2.1: Preparing input: network and demand data
10:45AM ~ 11:00AM	Break (Coffee and cookies are provided)
11:00AM ~ 12:00PM	Module 2.2 Model calibration
12:00PM ~ 1:00PM	Lunch Break
1:00PM ~ 1:45PM	Module 3: Understanding DTA Modeling Outputs
1:45PM ~ 2:30PM	Module 4: Working through Visualization Features in NEXTA
2:30PM ~ 3:15PM	Module 5: Hands-on case study of I-270 work zone evaluation
3:15PM ~ 3:30PM	Wrapping up

Workshop Purpose and Objectives

Purpose

- Equip workshop attendees with capabilities to apply Dynamic Traffic Assignment (DTA) modeling and simulation to a variety of applications through hands-on exercises using the open-source DTALite-NeXTA software tool

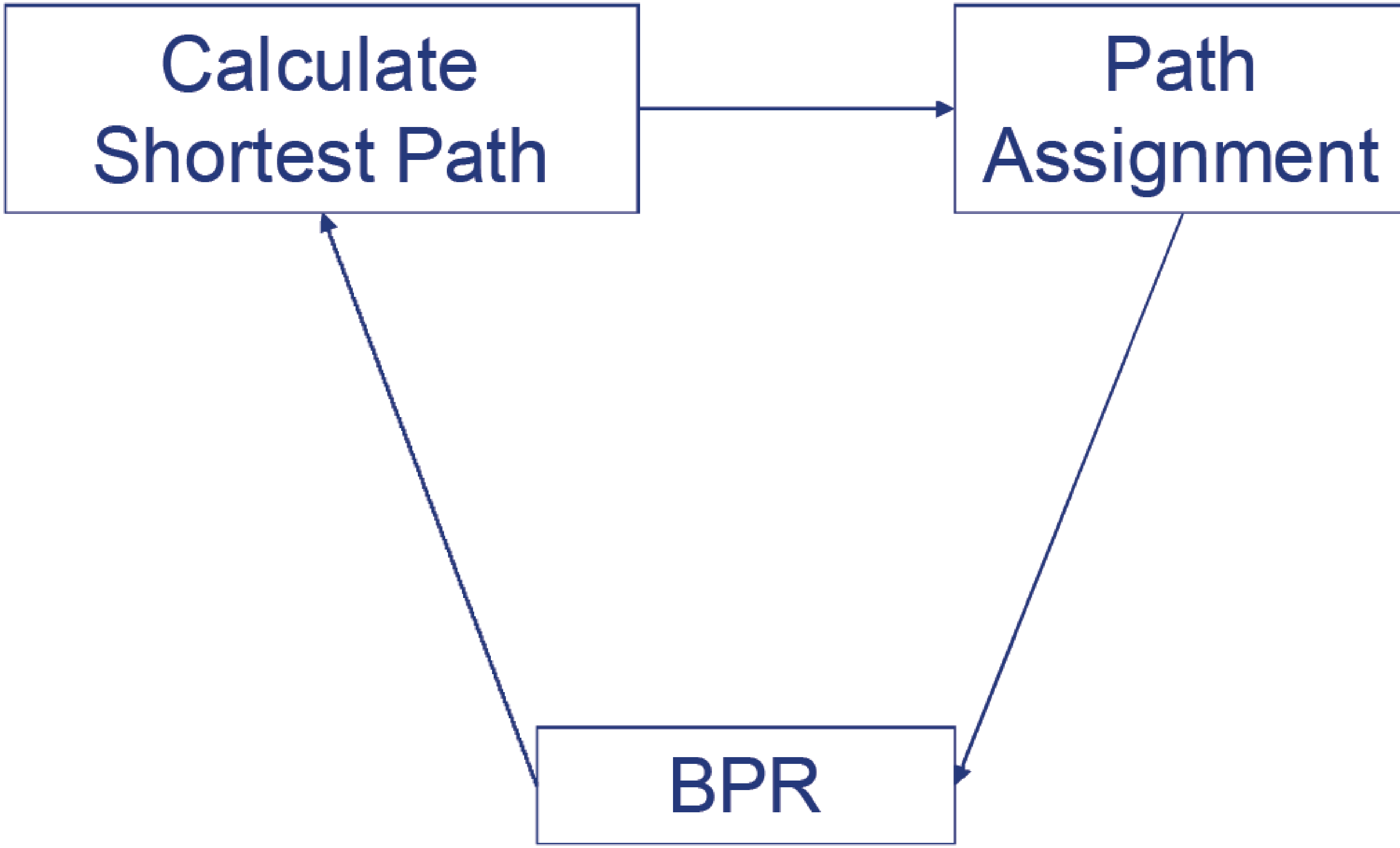
Learning Objectives

- Understand basic modeling approaches in DTALite
- Import data to code and modify a transportation network
- Evaluate simulation results using the visualization and reporting features in NeXTA
- Analyze toll facilities and work zones through in-workshop exercises
- Understand how DTALite can be used for additional applications (e.g., TSM&O, ICM, ATM).

Static User Equilibrium Traffic Assignment

- UE Principle: All used paths between the same OD pair have equal and minimum travel time
- Initial Solution: All-or-nothing assignment based on free-flow travel times
- Iteration Step 1: Find direction
  - Find shortest paths based on current travel times
  - All-or-nothing assignment on the new shortest paths
- Iteration Step 2: Find Step Size
  - Simplicial decomposition taking advantage of the obj. fn.
  - The optimal step size determines how much flow will be assigned to the new shortest paths
- Iteration Step 3: Update Travel Times
  - Based on link volume-delay function, e.g. BPR function
- Check for convergence

Static Traffic Assignment Algorithms



Motivation for Dynamic Traffic Assignment

- Link and path travel time is time-varying
- Congestion is more complex than the BPR-type volume-delay function (queue spillback, observed VC ratio <=1) that assumes away link interdependencies
- The experienced travel time at a link depends on when users arrive at that link
- Need for improved understanding of actual routing behavior and learning processes
- Representation of traffic operations, control devices, and other ICM/ATM/TDM/ATIS/TSM&O strategies in model

Motivation for DTA: Practical Needs

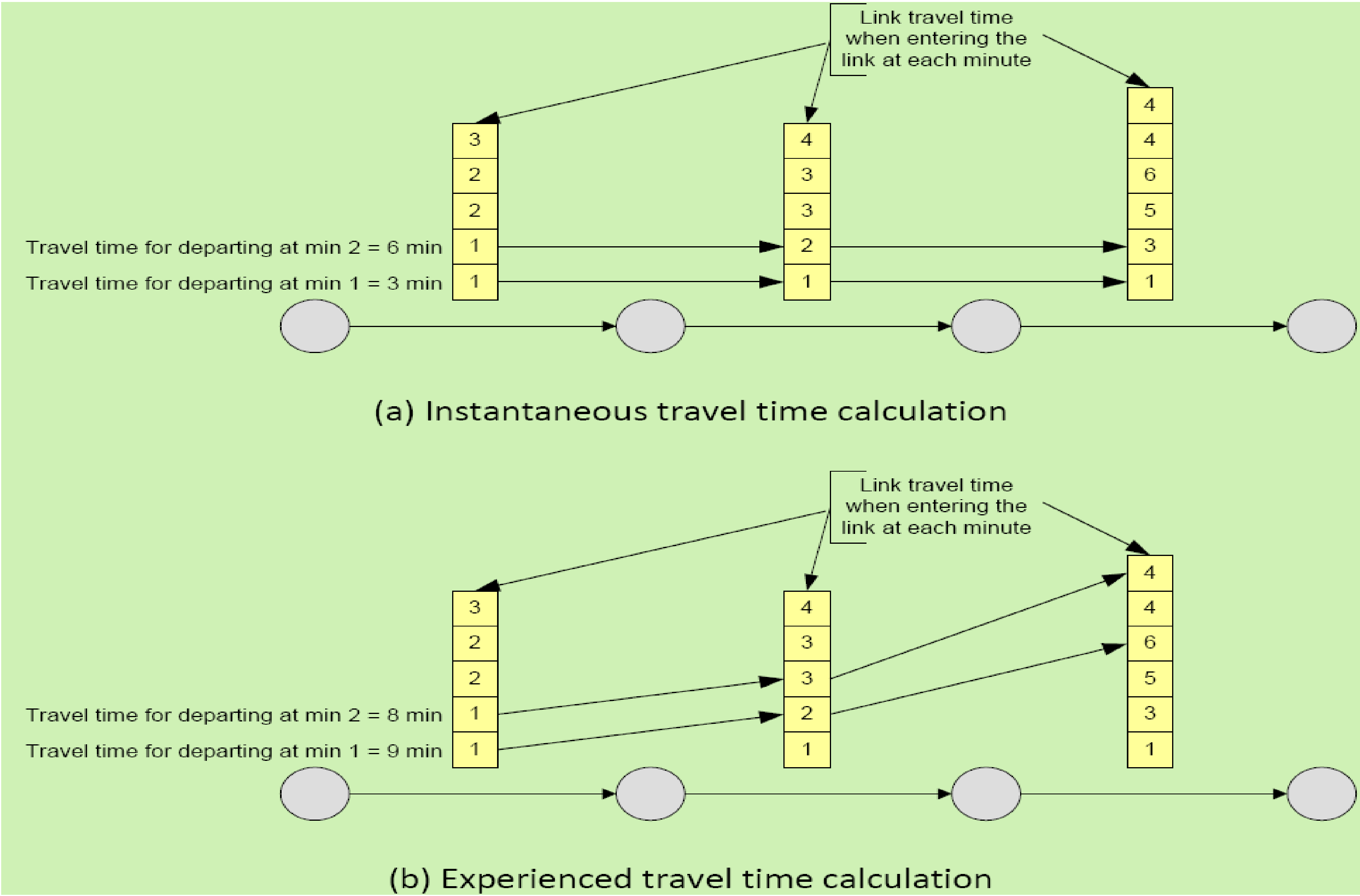
- Macro: Travel Demand Model
- Micro: Traffic Simulation Model
- Many transportation planning and operations applications require the integration of travel behavior/demand and traffic simulation models
- Simply integrating macro and micro models will not work in practice
- Need mesoscopic tools to enable the integration
- Meso: Dynamic Traffic Assignment, Agent-Based Method

Dynamic User Equilibrium for DTA

- DTA models attempt to solve for the Dynamic User Equilibrium, which states that all users with the same OD pair and departing at the same time have the same and minimum **experienced travel time.**

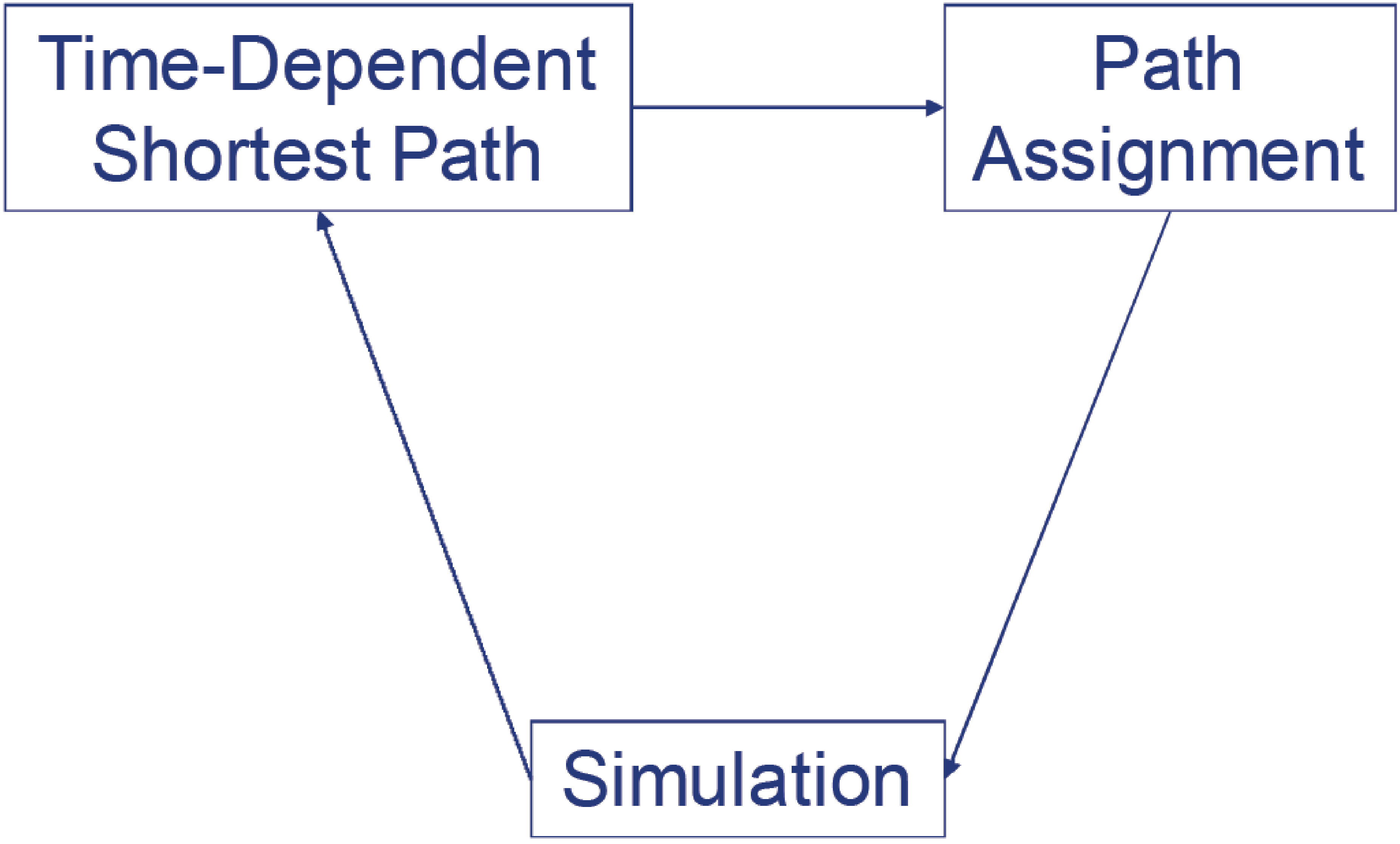
- Exception: Disequilibrium/Behavioral DTA

Experienced Travel Time

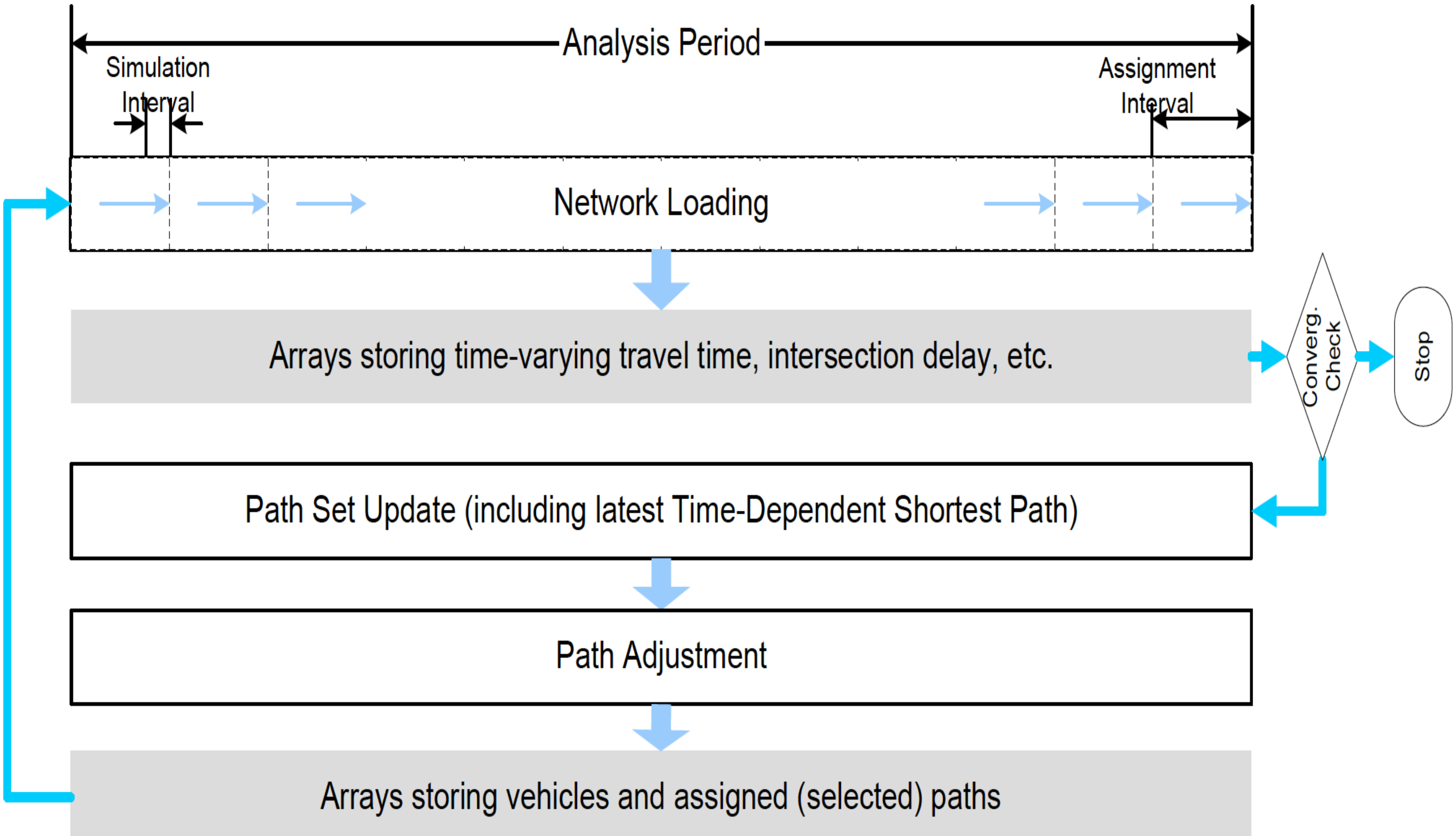


TRB DTA Primer: http://onlinepubs.trb.org/onlinepubs/circulars/ec153.pdf

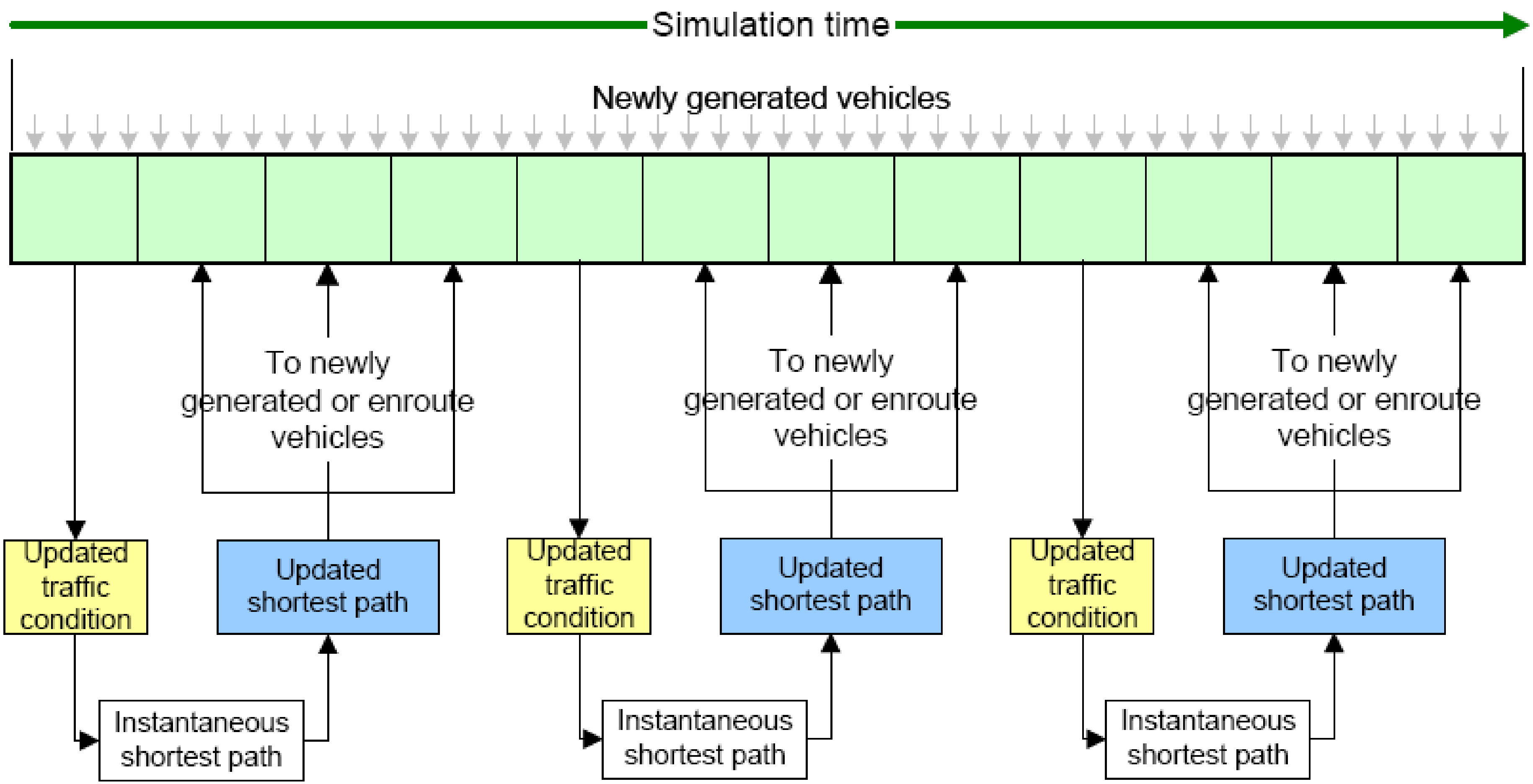
Simulation-Based DTA Algorithms



General DTA Model Structure



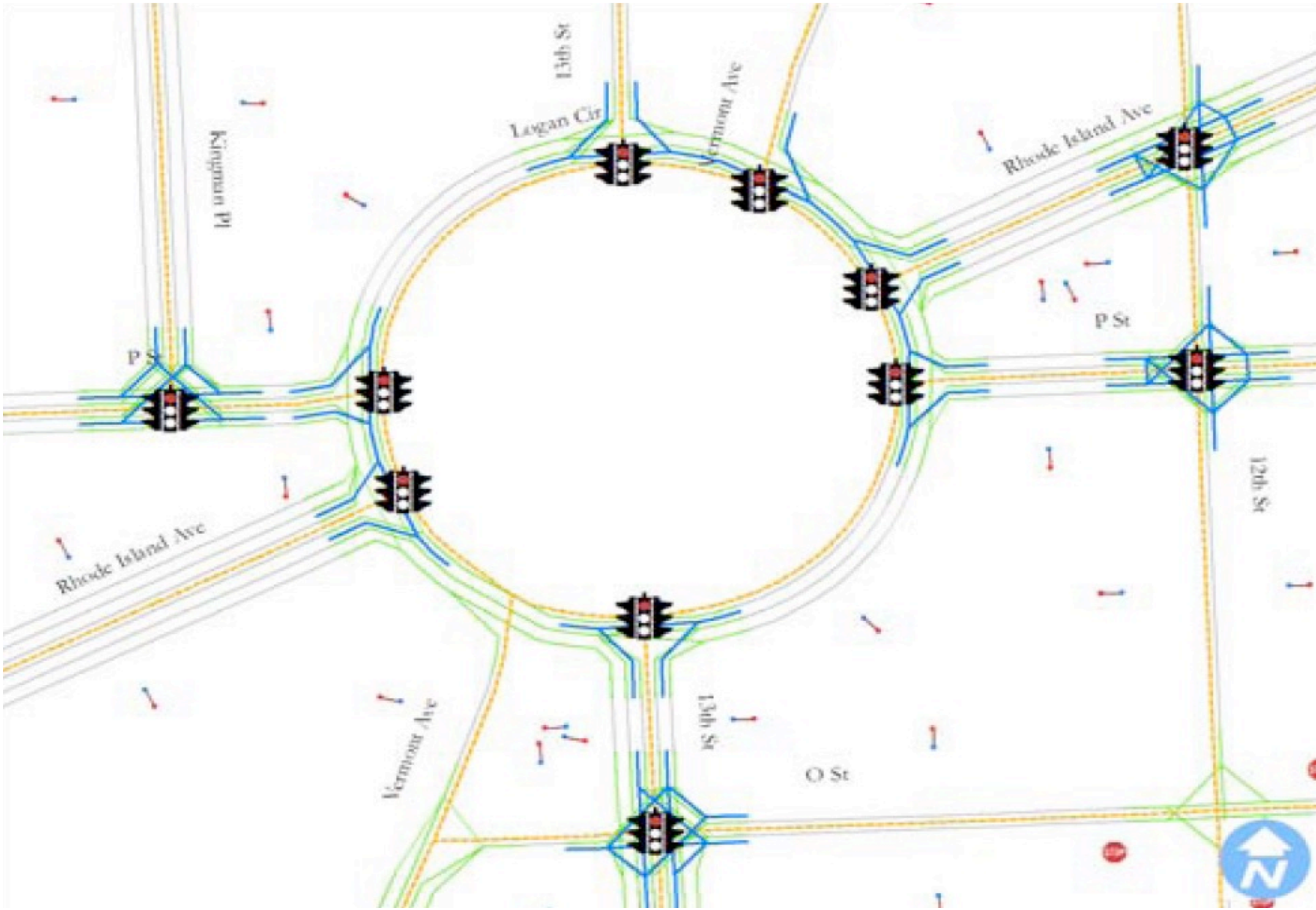
One-Shot/Pseudo DTA Implementation



Notable Simulation-Based DTA Tools

- DynaSmart (Mahmassani et al. 1992)
- TRANSIMS (Los Alamos NL 1995)
- DynaMIT (Ben-Akiva et al. 1996)
- VISTA (Ziliaskopoulos and Waller 2000)
- DynusT (Chiu et al. 2006)
- MATSim (Nagel and Axhausen 2008)
- DTALite (Zhou et al. 2012)

DTA Traffic Control Details (Logan Circle in D.C.)



DTA Applications: When and How

1 Geographic Scope

What is your study area?

- Isolated Location
- Segment
- Corridor/ Small Network
- Region

2 Facility Type

Which facility types do you want to include?

- Isolated Intersection
- Roundabout
- Arterial
- Highway
- Freeway
- HOV Lane
- HOV Bypass Lane
- Ramp
- Auxiliary Lane
- Reversible Lane
- Truck Lane
- Bus Lane
- Toll Plaza
- Light Rail Line

3 Travel Mode

Which travel modes do you want to include?

- SOV
- HOV (2, 3, 3+)
- Bus
- Rail
- Truck
- Motorcycle
- Bicycle
- Pedestrian

4 Management Strategy

Which management strategies should be analyzed?

- Freeway Mgmt
- Arterial Intersections
- Arterial Mgmt
- Incident Mgmt
- Emergency Mgmt
- Work Zone
- Spec Event
- APTS
- ATIS
- Electronic Payment
- RRX
- CVO
- AVCSS
- Weather Mgmt
- TDM

5 Traveler Response

Which traveler responses should be analyzed?

- Route Diversion
  - Pre-Trip
  - En-Route
- Mode Shift
- Departure Time Choice
- Destination Change
- Induced/ Foregone Demand

6 Performance Measures

What performance measures are needed?

- LOS
- Speed
- Travel Time
- Volume
- Travel Distance
- Ridership
- AVO
- v/c Ratio
- Density
- VMT/PMT
- VHT/PHT
- Delay
- Queue Length
- # Stops
- Crashes/ Duration
- TT Reliability
- Emissions/ Fuel Consump
- Noise
- Mode Split
- Benefit/Cost

7 Tool/Cost-Effectiveness

What operational characteristics are necessary?

- Tool Capital Cost
- Effort (Cost/ Training)
- Ease of Use
- Popular/Well-Trusted
- Hardware Requirements
- Data Requirements
- Computer Run Time
- Post-Processing
- Documentation
- User Support
- Key Parameters User Definable
- Default Values
- Integration
- Animation/ Presentation

Step 1: Prepare Input Data

- Demand Data
  - Time dependent OD trip table by vehicle type
  - Finer TAZ structure than that in the 4-step model
  - Sufficiently long study period to clear loaded vehicles
- Network Data
  - Start with the nodes and links in 4-step model
  - Add information such as number of lanes, turning lanes, merging/diverging lanes, prohibited movement/vehicle type, curvature, lane connectivity, etc.
- Control Data
  - Intersection signal timing, ramp metering, stop signs, yield signs, roundabouts, etc.
- Scenario Data

Step 2: Develop a DTA Model

- Desired output
- Type of application
- Size of the study area
- Traffic representation (micro vs. meso)
- Underlying travel behavior assumptions
- Budget
- Time
- Staffing
- Etc.

Step 3: Calibration/Validation

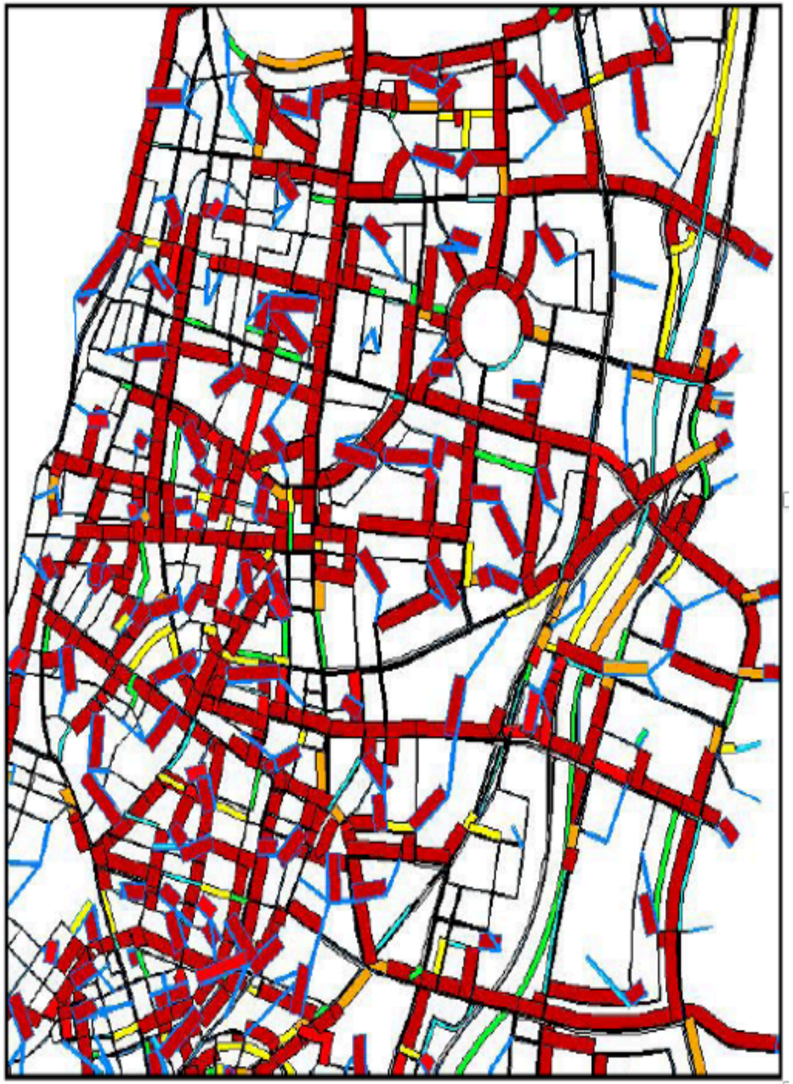
- Data for DTA model calibration/validation
  - Vehicle counts (by link or by lane)
  - Average vehicle speeds at detector locations
  - Average link/segment density or detector occupancy
  - Queue lengths
  - Link or sub-route travel times
  - Intersection Turning movement counts
- Address data inconsistency and variability

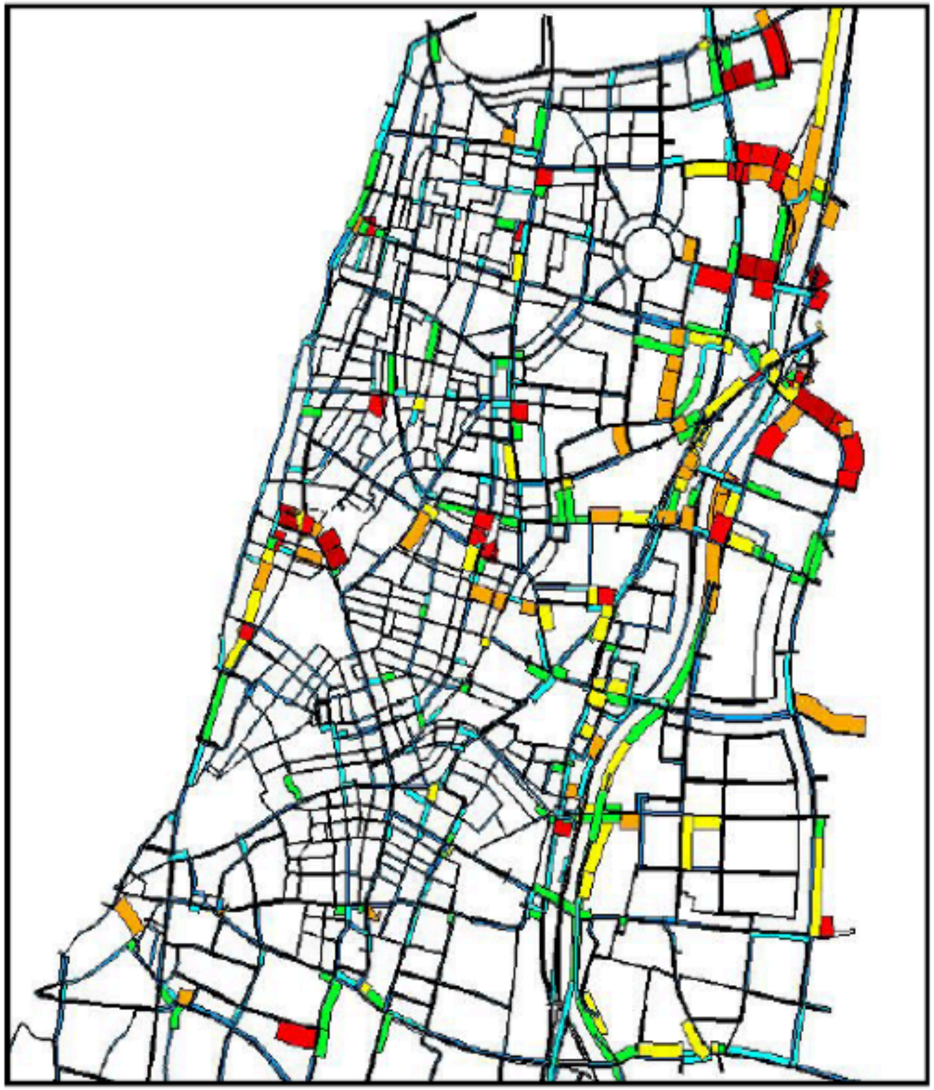
Step 3: Calibration/Validation (cont.)

- Preliminary calibration/validation (Qualitative)
  - Correct input/network coding errors, identify and eliminating unrealistic gridlocks, and achieve stable and reasonable network conditions
- Comprehensive calibration/validation (Quantitative)
  - Compare DTA model outputs with observed network conditions and adjust model inputs and parameters in a systematic way
  - A naïve method would involve identifying traffic count outliers, addressing them one at a time, and hoping for good luck (Not recommended)
  - Systematic/automated methods have been developed, but their performance vary from case to case

Excessive Congestion → Input Errors

Network at 9:00





Step 4: Characterize DTA Model Outputs

- Network-Wide Measures
  - Convergence measures, e.g. relative gap
  - Number of vehicles in the network
  - Number of vehicles waiting to enter the network
  - Network average speed/density
  - Network clearance time after study period
- Link-Level Measures
  - Inflow, outflow, turning flows, density, speed, queue length
- Route/Sub-Route Measures
  - Travel Time, reliability
- Agent/Individual-Level Measures

Step 5: DTA Application/Scenario Analysis

- Code build and no-build scenarios
- When used for future-year analysis, there are several issues:
  - Traffic control in the future year
  - Time-dependent OD demand in the future year

Step 6: DTA Model Maintenance and Update

- Monitor system conditions and changes
- Adjust DTA model input accordingly
- Re-calibrate the DTA model for new applications or when new calibration/validation data are available
- Integration of DTA model with Activity/Agent-based travel demand model (next workshop)
- Zoom-in/focusing approach for easier modeling maintenance and updates, i.e., only maintain one single DTA model for the entire jurisdiction and then used a zoom-in subarea version for applications

Brief Introduction to DTALite

- Agent-based simulation
- Capacity-constrained model
- Traffic simulation models
  - BPR, volume-delay functions
  - Point Queue
  - Spatial Queue (with jam density)
  - Newell’s Model

Practice Ready Tools

- Existing technical barriers: (based on DTA user survey, TRB network modeling committee, 2009)
  - Require too many input data: 47%
  - Take too long to run: 35%
  - Model is unclear: 35%

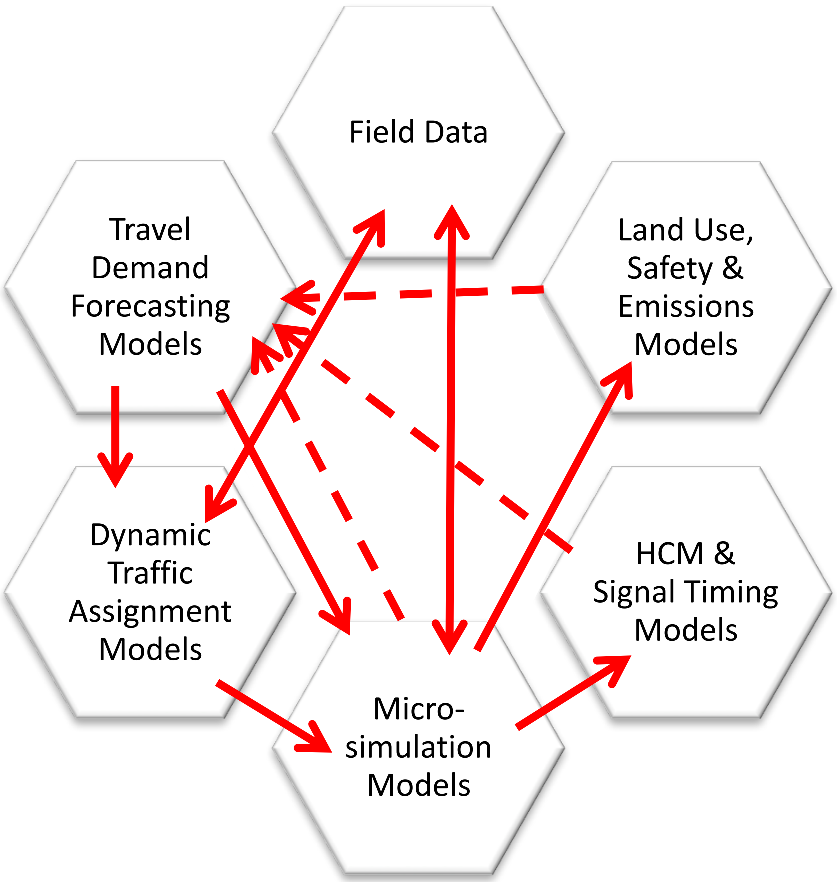
DTALite Goals

- Simplified data input from transportation planning models, Synchro etc.
- Use parallel computing capability, more efficient routing and simulation methods
- Open-source

Visualization: Seeing is believing
Excel Tools: Start from basics

Integrated Data and Modeling Practice

Current Practice
Ad Hoc



Integrated Data and Modeling Practice

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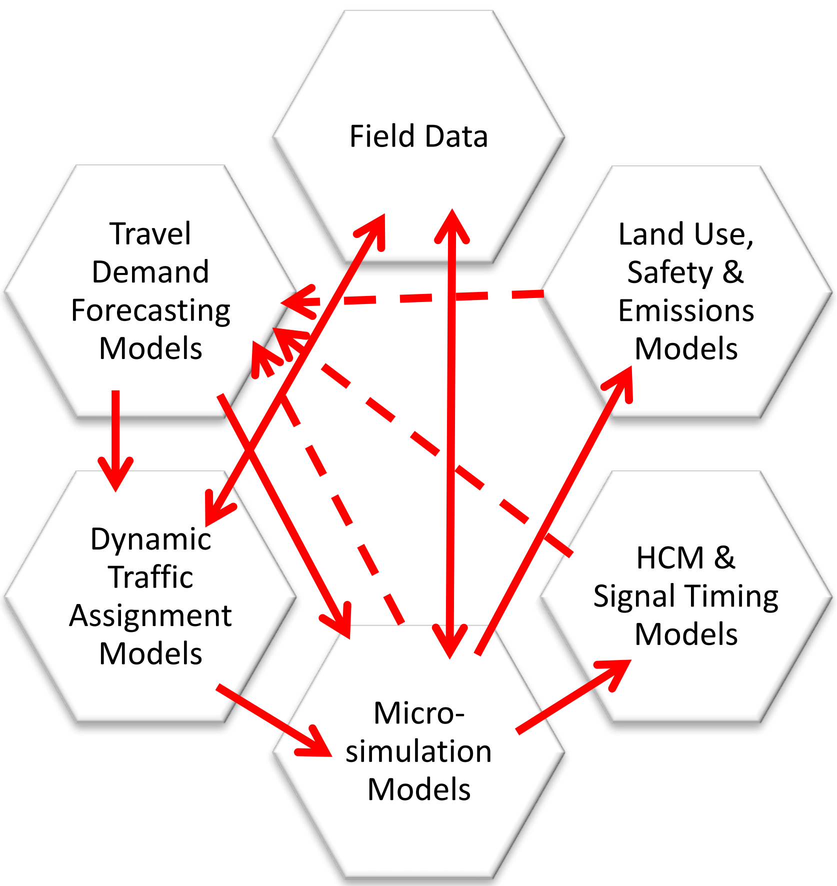
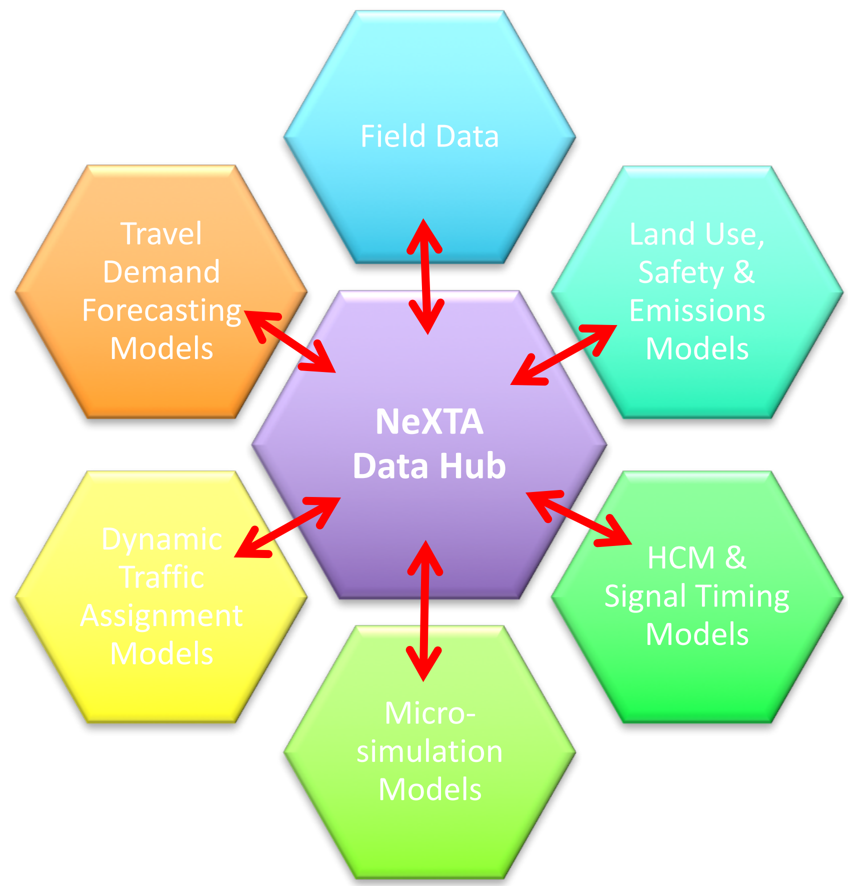


With NeXTA Data Hub
Systematic

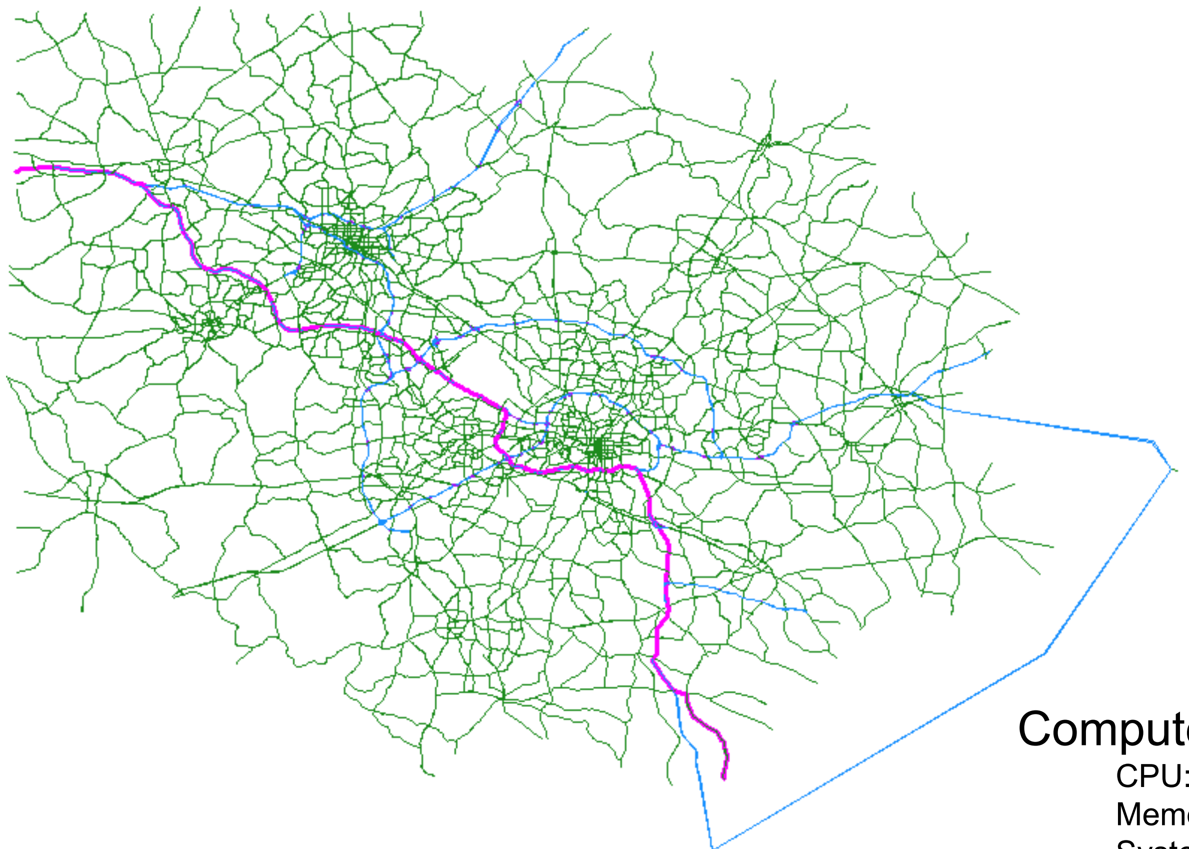


DTALite Features

1. Large-scale dynamic traffic assignment
   1. Successful implementation on the entire D.C.-Baltimore regional all-street network with 8 million agents.
2. Network scenario analysis and applications
   1. Road pricing application: Consider time-dependent toll, Heterogeneous Value of times
   2. Emission study: Fast simulation for emission analysis (with MOVES Lite)
   3. Any many more applications
3. Open-source simulator and data Hub
   1. Integrated simulated and measured data management tools
   2. Connection with microscopic simulation (VISSIM)

Fast Simulation

– A rigorous and computationally efficient tool to evaluate numerous alternatives analyses



Network Statistics
Triangle Corridor Network (NC, USA)

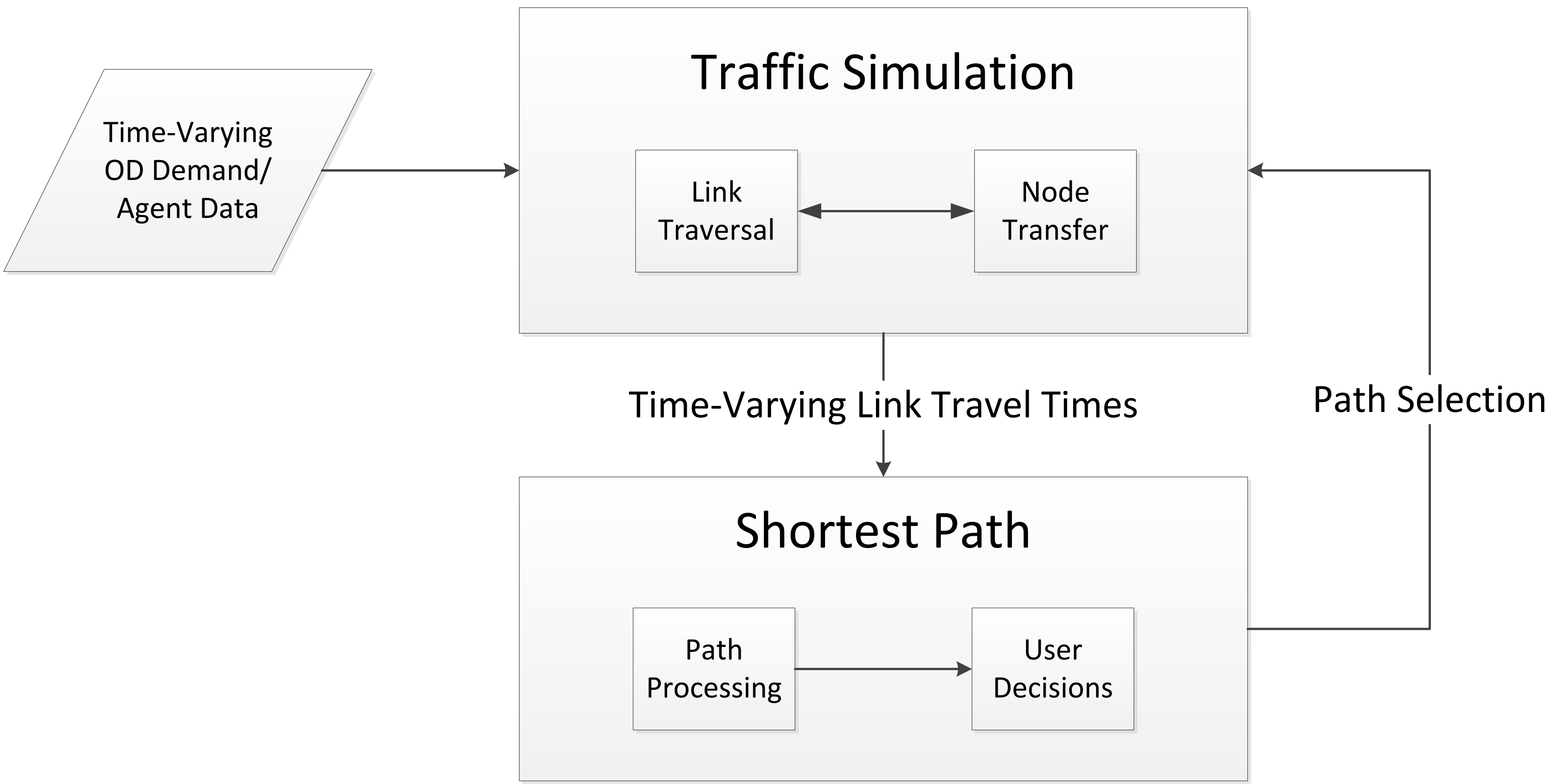
Zones = 2,389
Nodes = 9,528
Links = 20,258
Signals = 1,914
AM Trips = 1,064,703
Households = 490,000

2 min. 45 sec. / iteration
1hour for 20 iterations

Computer System Specification:

CPU: Intel i7-2960XM @ 2.70 GHz *8
Memory: 16.0 GB
System Type: 64-bit Windows 7

DTALite Simulation Iterations



Individual Agent Behavior Modeling

- Individual generalized cost function

$$Cost = Travel\ Time * VOT + Toll$$

  - Can consider multiple factors
    - Agent-specific value of time, value of reliability, value of safety, preference, socio-demographics, attitude, etc.
  - Perform routing algorithm individually for each vehicle/agent
  - Can adjust origin/destination/departure time/path at each iteration or within each iteration

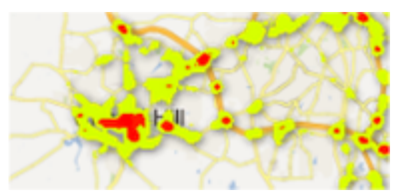
Rich Outputs

Ability to produce every vehicle's individual trajectory on network, and results at link, node, link group, subarea and system-wide levels

NeXTA

Large-scale Dynamic Traffic Assignment & Simulator

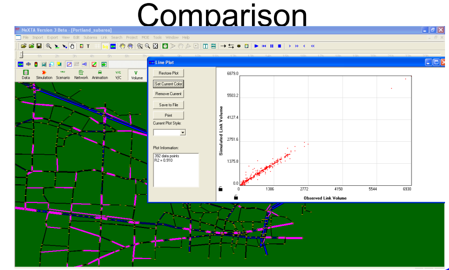
Google Earth/Maps



Other Visualization

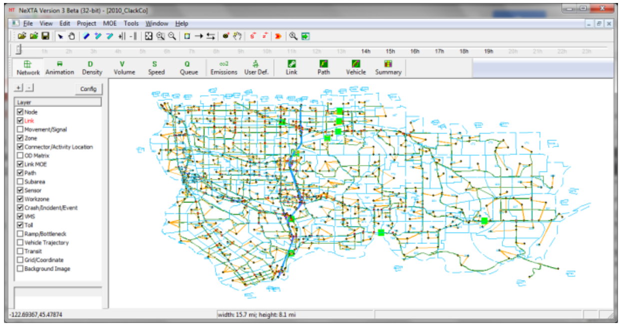
Corridor-level VOC contour

Simulation vs. Observation Comparison



Open-source Free Software Package

- NEXTA: front-end GUI (C++)
  - Version 2: GUI for TRANSIMS and DYNASMART
  - Version 3: GNU Open-source data hub
    - Import
      - Other regional planning models (TransCAD, VISSUM, Cube)
      - GIS shape files (household data without node layer)
      - Traffic volume, speed, GPS data, Google Public Transit Feed
    - Export
      - Google Earth, Google fusion tables
      - Prepare network and signal data for Synchro and VISSIM (through QEM)



- DTALite: Open-source computational engine (C++)
  - Light-weight and agent-based DTA
  - Built-in OD demand matrix estimation (ODME) program