DEVELOPMENT AND CALIBRATION OF REGIONAL DYNAMIC TRAFFIC ASSIGNMENT MODELS

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Outline

- Introduction to DTA system
- Reno/Sparks model
Outline

- DTA introduction
- Reno/Sparks model
Static Traffic Assignment (STA)

- **V/C can be more than 1**
- **No spill back**
  - The assigned **link volume can be considered as demand**—trips desired to traverse the link—instead of the actual flow.
  - In a static model, **FIFO** means that all vehicles traveling on the link experience the same travel time. What this implies is that there is no overtaking between vehicles and, in particular, this means **no overtaking between vehicles that exit the link by different turning movements**.
  - As there is no explicit representation of individual lanes in static models, there can be **no distinction between the traffic conditions on different lanes of the same link**. There is no way to represent the fact, for example, that the outside lane of a freeway is at a crawl due to an oversaturated off-ramp, while the other lanes are moving at a higher speed.
Other limitations include, for example, modeling of signal synchronization, modeling of lane-based effects, such as high-occupancy vehicle (HOV) or high occupancy toll (HOT) lanes, as they require representing the special lane as a parallel link. Most intelligent transportation systems (ITS)–related applications, such as traveler information systems and advanced network control schemes (e.g., adaptive control and ramp metering), are beyond the modeling capabilities of static assignment models.

The widely recognized advantages of static models, including the ability to solve large-scale problems, to converge to precise equilibriums and to provide consistency of solutions (if a proper algorithm is used with a sufficient number of iterations) have been aiding policy–project decision making for agencies for decades.
Dynamic traffic assignment is based on experienced travel costs.

At the moment that the link inflow becomes equal to the outflow, then the congestion continues to spread upstream into whichever upstream links are feeding traffic into the congested link. The outflows of these links are thus reduced, and the process repeats as described above. This queue spillback process also describes how a long queue (congested traffic) can be represented over a sequence of links in a dynamic traffic model.

- Identify the needs for DTA
- Develop processes for use of DTA
- Test applications of DTA (e.g., managed lanes, freight, ATDM, work zones)
- Microscopic models simulate the movement of individual vehicles based upon car-following, lane-changing, and gap-acceptance theories.
- Newer microscopic models are route based, meaning vehicles select a route at departure and follow that route with or without further update along the journey during simulation.
- For example, the one-shot (non-iterative) assignment-simulation approach is commonly used in some microsimulators, in which vehicles departing at different times are given a route that is periodically updated in simulation based on instantaneous travel times—snapshot travel time measured at the time that the routes are generated without considering congestion during subsequent time periods.
Static vs. Dynamic

**Static Assignment**
- Speed, density, and queues are not directly considered
- One solution
- Based on FIFO
- No representation of individual lanes
- All travelers for same O-D pair experience same travel time

**Dynamic Assignment**
- If link outflow < link inflow, travel time increases due to queues and density
- Iterative process to determine solution
- Not all based on FIFO
- Individual lanes are considered
- All travelers for same O-D pair for same departure time experience same travel time
Dynamic Traffic Assignment

• Advantages
  • More realistic traffic assignments
  • Automatic assignments save time from manually assigning
  • Evaluate different roadway situations
    – Lane closures
    – Tolls
    – New roadways
    – New developments

• Disadvantages
  • Iterative process
  • Takes time to set up and check the network
  • Network must be accurate to achieve best assignment
Dynamic Traffic Assignment

- Best to use on large, complex networks
  - City-wide modeling and planning
  - Traffic management for short- or long-term disruptions
  - Downtown traffic management and street configurations
  - Managed lanes
  - HOV or HOT lanes
  - New interchange
  - Tolling facilities
- Not good for simple TIA’s
Experience Travel Time vs. Instantaneous Travel Time

The time-varying link travel times are assumed to be provided by the network loading procedure.

(a) Instantaneous travel time calculation
(b) Experienced travel time calculation
Example
Instantaneous Route Travel Time Calculation
(Shortest Route for Departure Time 1)

(I-A) Travel time for Route 1-2-4-6 = 1+1+1 = 3

(I-b) Travel time for Route 1-2-5-6 = 1+2+1 = 4

(I-c) Travel time for Route 1-3-5-6 = 2+2+1 = 5

 Experienced Route Travel Time Calculation
(Shortest Route for Departure Time 1)

(E-a) Travel time for Route 1-2-4-6 = 1+2+6 = 9

(E-b) Travel time for Route 1-2-5-6 = 1+3+1 = 5

(E-c) Travel time for Route 1-3-5-6 = 2+1+1 = 4
Instantaneous Route Travel time Calculation (Shortest Route for Departure Time 2)

(I-A) Travel time for Route 1-2-4-6 = 1+2+3 = 6

(E-a) Travel time for Route 1-2-4-6 = 1+3+4 = 8

(I-b) Travel time for Route 1-2-5-6 = 1+3+2 = 6

(E-b) Travel time for Route 1-2-5-6 = 1+3+1 = 5

(I-c) Travel time for Route 1-3-5-6 = 1+2+2 = 5

(E-c) Travel time for Route 1-3-5-6 = 1+1+1 = 3
Microscopic vs Mesoscopic

- **Microscopic**
  - Small time steps (0.1 second)
  - Car following, lane changing, reaction times
  - Explicit models of traffic control, lane utilization
  - Routing utilizes lanes, intersection geometry and delays
  - Outputs: Detailed trajectories, realized capacities

- **Mesoscopic**
  - Large time steps (several minutes)
  - Macroscopic traffic dynamics e.g. speed-density functions
  - Approximate models of signals, lanes, capacities
  - Routing based on link-node representation
  - Outputs: Aggregate link performance
DTA is now well heard but still not well understood
Comparison of DTA and STA

### TABLE 1 Comparison Between Static Assignment and DTA Approximator

<table>
<thead>
<tr>
<th>Category</th>
<th>n</th>
<th>Vehicle-miles traveled (millions)</th>
<th>Average v/c</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Static</td>
<td>Dynamic</td>
</tr>
<tr>
<td>Freeway</td>
<td>6292</td>
<td>25.88</td>
<td>29.86</td>
</tr>
<tr>
<td>Principal Arterial</td>
<td>4936</td>
<td>6.46</td>
<td>5.39</td>
</tr>
<tr>
<td>Minor Arterial</td>
<td>10434</td>
<td>7.65</td>
<td>6.25</td>
</tr>
<tr>
<td>Collector</td>
<td>14596</td>
<td>2.97</td>
<td>2.74</td>
</tr>
<tr>
<td>Frontage Road</td>
<td>2783</td>
<td>1.56</td>
<td>1.44</td>
</tr>
<tr>
<td>Congested</td>
<td>2995</td>
<td>18.35</td>
<td>22.61</td>
</tr>
<tr>
<td>Uncongested</td>
<td>25997</td>
<td>28.61</td>
<td>25.11</td>
</tr>
</tbody>
</table>

### TABLE 2 Comparison Between Static Assignment and VISTA

<table>
<thead>
<tr>
<th>Functional class</th>
<th>Total travel time (hr x 10^2)</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Static</td>
<td>Dynamic</td>
</tr>
<tr>
<td>Freeways</td>
<td>505</td>
<td>325</td>
</tr>
<tr>
<td>Principal Arterials</td>
<td>174</td>
<td>543</td>
</tr>
<tr>
<td>Minor Arterials</td>
<td>237</td>
<td>715</td>
</tr>
<tr>
<td>Collectors</td>
<td>227</td>
<td>738</td>
</tr>
<tr>
<td>Frontage Roads</td>
<td>45</td>
<td>390</td>
</tr>
<tr>
<td>Total System</td>
<td>1266</td>
<td>3086</td>
</tr>
</tbody>
</table>
Outline

- DTA definition
- DTA software packages
- Reno/Sparks model
- Dynamic bus demand assignment
DTA Software Packages

- DTALite
- DynusT
- DynaMIT-R, DYNASMArt-X, DynaMIT-P and DYNASMRAT-P
- Dynameq
- TransModeler
- …
TransModeler Overview

- Hybrid simulation (scalable micro, meso, and macro simulation)
- Integrated travel demand and traffic modeling
- Built-in Geographic Information System
- Network accuracy, model fidelity, charting
- Explicit handling of complex traffic control
- Intelligent Transportation Systems (ITS)
  - High Occupancy Vehicle/Toll (HOV/HOT)
  - Electronic tolls (ETC)
  - Variable/Changeable Message Signs (VMS/CMS)
- Dynamic Traffic Assignment (DTA)
Challenges for Model Comparison

- Traffic simulation tools differ significantly
  - Software architecture
    - Data structures, loop implementation, procedures
  - Modeling features, assumptions, simplifications
    - Vehicle and user classes, value of time (VOT)
    - Network representation
      - Lanes, lane groups, turn bays
      - Shortest path, vehicle propagation algorithms
  - Default parameters
  - Visualization and output generation
Challenges for Model Comparison

- Literature review indicates diverse tool-dataset combinations
  - Comparison of existing studies is difficult
    - Need for calibration to common traffic data
    - Unclear methodologies for prior calibration
    - Differing performance measures, thresholds
  - Often impossible to replicate datasets across tools
    - Limited documentation of algorithms, assumptions
    - Missing data
    - Incompatible modeling assumptions
Outline

- DTA definition
- Reno/Sparks model
Reno/Sparks model

- **List of Tasks**
  1. DTA Lite/NeXTA explanation
  2. Data collection
  3. DTA model calibration
  4. Case studies
  5. Issues
Open-source Free Software Package

- **NEXTA: front-end GUI (C++)**
  - **Import**
    - Other regional planning models (TransCAD, VISSUM, Cube)
    - GIS shape files
    - Traffic volume, speed, GPS data, Google Public Transit Feed
  - **Export**
    - Google Earth, Google fusion tables

- **DTALite: Open-source computational engine (C++)**
  - Light-weight and agent-based DTA
  - Built-in OD demand matrix estimation (ODME) program
Dynamic Origin-Destination Demand Matrix Estimation (ODME) in DTALite

<table>
<thead>
<tr>
<th>File Group</th>
<th>Input file list</th>
<th>Remark</th>
<th>Output file list</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demand</strong></td>
<td>1. input_demand.csv or input_agent.csv</td>
<td>Demand content for specifying distribution</td>
<td>1. output_agent.csv</td>
<td>Final estimation results represented in terms of agent trajectory format</td>
</tr>
<tr>
<td></td>
<td>2. input_demand_file_list.csv</td>
<td>Demand file specification, specify temporal departure time distribution</td>
<td>2. ODME_zone_based_log.csv 3. ODME_final_result.csv</td>
<td>Zone based production based ratio; Iteration by iteration zone based total production adjustment</td>
</tr>
<tr>
<td><strong>Sensor</strong></td>
<td>1. input_link.csv</td>
<td>Store count_sensor_id, speed_sensor_id for referring sensor data</td>
<td>1. ODME_link_based_log.csv</td>
<td>Iteration by iteration link based flow adjustment</td>
</tr>
<tr>
<td></td>
<td>2. sensor_count.csv</td>
<td>Link based sensor count data</td>
<td>2. debug_validation_results.csv</td>
<td>Link based simulated vs. observed results</td>
</tr>
<tr>
<td></td>
<td>3. sensor_speed.csv (optional)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Scenario</strong></td>
<td>1. input_scenario_settings.csv</td>
<td>ODME and assignment settings</td>
<td>1. output_summary.csv</td>
<td>Iteration-by-iteration UE and ODME statistics</td>
</tr>
<tr>
<td></td>
<td>2. DTASettings.txt</td>
<td>Default settings for sequential ODME run</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. scenario_work_zone.csv</td>
<td>Specify the capacity reduction scenarios in the estimation and prediction stages</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Sample Data

Sample data in sensor_count.csv

<table>
<thead>
<tr>
<th>count_sensor_id</th>
<th>from_node_id</th>
<th>to_node_id</th>
<th>day_no</th>
<th>start_time_in_min</th>
<th>end_time_in_min</th>
<th>link_count</th>
<th>speed</th>
<th>travel_time_in_min</th>
<th>lane_density</th>
</tr>
</thead>
<tbody>
<tr>
<td>5010-&gt;4958</td>
<td>5010</td>
<td>4958</td>
<td>1</td>
<td>990</td>
<td>1050</td>
<td>49.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4958-&gt;5010</td>
<td>4958</td>
<td>5010</td>
<td>1</td>
<td>990</td>
<td>1050</td>
<td>74.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4952-&gt;5022</td>
<td>4952</td>
<td>5022</td>
<td>1</td>
<td>990</td>
<td>1050</td>
<td>221.5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sample data in input_link.csv

<table>
<thead>
<tr>
<th>link_id</th>
<th>from_node_id</th>
<th>to_node_id</th>
<th>direction</th>
<th>length</th>
<th>number_of_lanes</th>
<th>speed_limit</th>
<th>lane_capacity</th>
<th>count_sensor_id</th>
<th>speed_sensor_id</th>
</tr>
</thead>
<tbody>
<tr>
<td>1285</td>
<td>1285</td>
<td>5018</td>
<td>1</td>
<td>0.2384</td>
<td>7</td>
<td>21</td>
<td>1428.6</td>
<td>1285-&gt;5018</td>
<td></td>
</tr>
<tr>
<td>1286</td>
<td>1286</td>
<td>11125</td>
<td>1</td>
<td>0.466</td>
<td>7</td>
<td>21</td>
<td>1428.6</td>
<td>1286-&gt;11125</td>
<td></td>
</tr>
<tr>
<td>1289</td>
<td>1289</td>
<td>4952</td>
<td>1</td>
<td>0.2427</td>
<td>7</td>
<td>21</td>
<td>1428.6</td>
<td>1289-&gt;4952</td>
<td></td>
</tr>
</tbody>
</table>
Sensor Data

Bridge Construction
## Scenario Settings

<table>
<thead>
<tr>
<th>Data Field</th>
<th>Value</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>number_of_iterations</td>
<td>50</td>
<td>The total number of iterations for ODME</td>
</tr>
<tr>
<td>traffic_flow_model</td>
<td>1</td>
<td>This parameter defines a specific traffic flow model used in both assignment and ODME of DTALite; 1 indicates a point queue model in this example. The selection of Newell’s KW model is also feasible.</td>
</tr>
<tr>
<td>signal_representation_model</td>
<td>0</td>
<td>This parameter defines a specific signal control for DTALite.</td>
</tr>
<tr>
<td>traffic_assignment_method</td>
<td>3</td>
<td>This assignment method of “3” is dedicated to ODME</td>
</tr>
<tr>
<td>ODME_start_iteration</td>
<td>20</td>
<td>It defines the first iterative assignment period to converge to the user equilibrium state, and could generate a sufficient number of paths for path flow adjustment. The iteration number also indicate that ODME will begin at the 21th iteration.</td>
</tr>
<tr>
<td>ODME_end_iteration</td>
<td>50</td>
<td>It defines that ODME will end at the 50th iterations.</td>
</tr>
<tr>
<td>ODME_max_percentage_deviation_wrt_hist_demand</td>
<td>40</td>
<td>The maximum percentage of demand deviation from base-line dynamic demand.</td>
</tr>
<tr>
<td>ODME_step_size</td>
<td>0.05</td>
<td>Moving size of each step in path flow adjustment algorithm</td>
</tr>
<tr>
<td>calibration_data_start_time_in_min</td>
<td>990</td>
<td>This and the following parameter specify the time window for ODME to use the sensor data. Note that, users can prepare a long period of sensor data, say from 0 to 24 hours, but only use part of sensor data, say between min 990 and 1050, for calibration.</td>
</tr>
<tr>
<td>calibration_data_end_time_in_min</td>
<td>1050</td>
<td></td>
</tr>
</tbody>
</table>
Three-stage simulation for scenario analysis

- Stage 1: Traffic network data, Historical OD demand
- Stage 2: Sensor data (sensor_count.csv)
- Stage 3: Scenario files (scenario_work_zone.csv)

Flow:
- User Equilibrium to Route choice set
- Route choice set to ODME
- ODME to Estimated OD demand
- Estimated OD demand to Scenario analysis
- Scenario analysis to Total number of iterations
Progress

Task 4. DTA model calibration

- Step 1: Static Traffic Assignment
  - Performed BPR function in DTA
  - Compared results with TransCAD

\[ y = 0.9244x \]
\[ R^2 = 0.9313 \]
Part 1. Data for model calibration
- 24-hour link volumes
  - Retrieved data from TRINA
  - I-80, I-580, McCarran, Virginia, and Kietzke
  - 693 links in total (incl. 119 ramps)
  - Approximately 200 links extracted
- Travel speed and travel times
  - National Performance Management Research Data Set (NPMRDS) data from HERE
  - Travel times for April 2015 (5-min interval)
  - Extracted and mapped Nevada data
  - Converted travel times to speed
  - 240 links in total
  - To match the data with DTA network

Part 2. Data for case studies
- Link volume data for work zone
Model consistency with TransCAD

- **Links**
  - Consistent with TransCAD
  - Modified # of lanes to match reality

- **Zones/Demand**
  - Consistent with TransCAD

- **Control types**
  - Not available from Reno TransCAD model
24 Hours
Sensitivity analysis on number of detectors
Need to Load Time-dependent Demand Profile

Vehicle Miles Traveled (VMT)
26,509,423 5-Minute Points (56% Observed)
Segment Type: State, Segment Name: California
02/01/2005 00:00:00 to 02/20/2005 23:59:59 (Days=Mo,Tu,We,Th,Fr)

• Weekday demand profile in California,
• Feb, 2005 Source: PeMS
The Effect of Bridge Construction on Overall Performance

<table>
<thead>
<tr>
<th></th>
<th>Avg Travel Time (min)</th>
<th>Avg Distance</th>
<th>Avg Speed</th>
<th>Avg CO (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before Calibration</td>
<td>10.1377</td>
<td>6.90825</td>
<td>40.8866</td>
<td>10678.8</td>
</tr>
<tr>
<td>After Calibration</td>
<td>10.1393</td>
<td>6.90703</td>
<td>40.8729</td>
<td>10678.4</td>
</tr>
<tr>
<td>During Bridge Constr</td>
<td>10.1604</td>
<td>6.92574</td>
<td>40.8983</td>
<td>10697.5</td>
</tr>
</tbody>
</table>
Case Study Region AM Peak
Calibration on whole network

80% Interval

R^2 = 0.084

Observed Hourly Link Volume (AM Peak)
Simulated Hourly Link Volume (AM Peak)
Case Study Region AM Peak Calibration on Subarea
QEM signal timing toolbox was selected for traffic signal timing estimation. The current toolbox that we have does not give the estimated signal information to DTA model.

- Intersection links
Issues from Interviews with National DTA Users

- Required learning curve
- Level of effort and required modeling detail
- Required and available data types and quality
- Importance of calibration/validation
- Need for time-variant trip matrices
Thank you!

Questions or Comments?