Comparison of Simulation-Based Dynamic Traffic Assignment Approaches for Planning and Operations Management

Ramachandran Balakrishna
Daniel Morgan
Qi Yang
Howard Slavin

Caliper Corporation

4th TRB Conference on Innovations in Travel Modeling
Tampa, Florida
30th April, 2012
Outline

• Introduction
• Motivation
• The MAG DTA Project
  – Maricopa Association of Govts, Greater Phoenix
  – Project objectives, description and results
• Conclusion
Introduction

- Dynamic traffic assignment (DTA)
  - Captures within-day dynamics
    - Temporal demand-supply interactions
  - Relevant for several analyses
    - Emissions, operations, planning, etc.
  - Can use different network loadings
    - Analytical, microscopic, mesoscopic, macroscopic, hybrid
Motivation

• DTA is often equated with meso-
  – Tradeoffs between realism, running time
  – Few quantitative comparisons exist

• Micro DTA is more detailed and accurate
  – Realistic behavior models
  – Lane-level dynamics
  – High-fidelity outputs
    • e.g. trajectories, vehicle dynamics, signal delays

Feasible for large, congested networks
  • Greater Phoenix (MAG), Arizona; Jacksonville, Florida
MAG Project: Objective

- Demonstrate feasibility of large-scale, regional microscopic DTA
  - Dynamic user equilibrium (DUE)
    - Temporal extension of Wardrop’s principle
    - Same impedance (e.g. travel time) for all used paths between each OD pair, for a given departure time interval
MAG Project: Model Development

• Network development
  – Code highly accurate intersection geometry
  – Preserve real-world lane-level detail

• Model calibration
  – Estimate time-varying origin-destination (OD) flows and other parameters

• Dynamic traffic assignment (DTA)
  – Estimate congested, time-varying travel travel times
  – Platform: TransModeler (Caliper Corp.)
TransModeler Overview (I)

- Simulates urban traffic at many fidelities
  - Microscopic (car following, lane changing)
  - Mesoscopic (speed-density relationships)
  - Macroscopic (volume-delay functions)
  - Hybrid (all of the above)

- Employs realistic route choice models
- Handles complex network infrastructure
  - Signals, variable message signs, sensors, etc.
- Simulates multiple modes, user classes, vehicle types
TransModeler Overview (II)

- Simulation-based DTA
  - e.g. Link travel time averaging
MAG Project: Microscopic DTA (1)

- Greater Phoenix, Arizona
- ~500 square miles
- 17,000 nodes; 23,000 links; 890 zones; 1,800 signals
- AM and PM peak periods
  - 3 hours each
  - 1.5-2.0 million trips each
MAG Project: Microscopic DTA (II)

- Detailed GIS geography
  - Impacts on driver behavior
- Numerous cross-streets
- Explicit handling of signals, coordination, offsets
- Calibrated to match traffic data
MAG Project: Microscopic DTA (III)

- Running times: 28 minutes per 3-hour loading
- Hardware: dual 6-core 3.33 GHz (hyperthreaded), 48 GB RAM
Micro vs. Meso DTA

• Current need for evaluating tradeoffs
  • Meso not strong with vehicle types, user classes, signal delay, lane dynamics
  • Micro directly supports emissions modeling, etc.

• MAG run times per network loading
  • Micro: 28 min; meso: 11 min
  • Hybrid: 21 min

• TransDNA: regional meso DTA
  • Shares TransModeler architecture
  Allows objective accuracy comparisons
Conclusion

• Large-scale microscopic DTA is feasible
  - MAG (Arizona)
  - Jacksonville: DaySim demand outputs
  - Recent examples: Irvine and Eureka (California)

• On-going and future work
  - Objectively quantify micro-meso tradeoffs
  - Use common software architecture and data
    - Focus on algorithms, not implementation
    - TransModeler, TransDNA
Thank you!

Questions?
Model Calibration

- Estimate OD flows and supply parameters
  - Match field data: link counts, speeds, etc.
  
  $$(\beta^*, x^*) = \arg\min_{\beta,x} z(M, M, x, x^a, \beta, \beta^a)$$

  $$M = M + u$$
  $$x^a = x + v$$
  $$\beta^a = \beta + w$$
  $$M = f(x, \beta; G)$$

- Complex, non-linear, stochastic, large-scale
Simulation-Based DTA Framework (contd.)

- **Averaging method**

\[ X_{i+1} = (1 - \alpha_i)X_i + \alpha_i f[X_i] \]

*where:*

- \( X_i \) = Input to iteration \( i \)
- \( X_{i+1} \) = Output of iteration \( i \)
- \( f[] \) = Simulation model
- \( \alpha_i \) = Averaging factor

- **Choice of averaging factor**
  - Method of Successive Averages (MSA)
  - Polyak
  - Fixed-factor
TransDNA Overview

• Highly-scalable dynamic network assignment

• Powerful DTA algorithms on GIS platform
  – Mesoscopic traffic simulation
  – Route choice models
  – Multi-threaded engine

• Efficient regional model development
  – Minimal additional network coding
  – Accurate geometry and geography