Modeling Every Hill, Bus, Traffic Signal, and Car

How San Francisco Collaboratively Built a Citywide Dynamic Traffic Assignment Model

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SAN FRANCISCO COUNTY TRANSPORTATION AUTHORITY
TRB Planning Applications Conference
May 5th, 2013
Why DTA? (recap)

Better representation of the real world

- $v \leq c$
- Queues spill back to adjacent links
- Signals & intersection design matter
- Transit and cars interact

Less messy spreadsheet work

- Less subjectivity
- Fewer typos/errors
An additional tool in the toolbox - DTA

- **SF-CHAMP**: Regional static user equilibrium within an activity-based model
- **Dynamic Traffic Assignment**: Time-dependent user equilibrium with realistic, but simplified vehicle simulation
- **Traffic Microsimulation**: Highly realistic simulation of vehicle behavior and interactions
Why Collaboration?

Why not just ask for a “product”?

We have to own it in the end

“This code is inscrutable!”

“How do I do Validation or actually run a scenario?”

“We just don’t have the budget to get to that calibration target.”

“I don’t care, that’s what’s in the scope.”

Shared ownership / credit makes more people care and understand situation

We work with planners on real projects in SF every day.

“Shoot, Well what I really hoped DTA would be able to capture was…”

“These results don’t make any sense. I thought DTA was supposed to be useful!”

Cool Project – Let lots of interested and smart people take part and learn!

See Lisa Zorn present “The Codebase IS the Deliverable” Monday 10:30
DTA Model Development Objectives (for now)

- Have a working DTA model with results that make sense for the **PM Peak** period in **San Francisco**
- Have seamless process from SF-CHAMP to DTA results:
  - Little human intervention
  - Reduce human error
  - Use SF-CHAMP demand directly
    - Behaviorally consistent
  - Allow SF-CHAMP to take advantage of all fixes
DTA Model Development Approach

• Write code when possible for repeated human tasks
  • Don’t re-write code that exists in our DTA package
  • Develop in an open source environment
• Use as much ‘real’ data as possible
• Fix all issues “at the source” if possible
Where we were starting from in SF-CHAMP

Every transit stop
Every transit line
Every street
Every Hill

981 Zones in SF
DTA ANYWAY CODEBASE & INPUT DEVELOPMENT

Input

Codebase

Calibration
DTA Anyway for Automation

Static Network

Static Network + Projects

Python Scripts

DTA Anyway Python Module

DTA Network

DTA Network + Projects
**DTA Anyway Can**

- Read Cube Networks / text-based static networks
- Read/Write Dynameq ASCII files
- Write GIS shapefiles
- Typical network edits

**DTA Anyway Cannot**

- Visualize anything directly
- Read/Write DTA networks for other DTA software (but designed to make this easily implementable)
DTA Inputs

http://dta.googlecode.com
Input Development
(alongside codebase development)

Signals
- 1,100 signals
- Actuated signals approximated to fixed
- Source: SFMTA-defined Excel files

Demand
- CHAMP Demand
- 620k vehicles 2:30-7:30 PM
- 976 zones + 22 Exts
- Time profile f(counts)

Stops
- 1,845 AWSC
- 919 TWSC
- Source: SFMTA GIS

Transit
- 236 Lines
- Source: SF-CHAMP Cube Files
CALIBRATION AND VALIDATION
“Model Calibration involves the identification of a set of DTA model inputs and parameters that results in model outputs that are reasonably close to those field observations.”

- DTA Primer
Model Calibration Approach

1. Ensure quality inputs
2. Measure anything that can be measured
3. Evaluate the results qualitatively
4. Evaluate the results quantitatively
5. Make defensible adjustments

What factors that affect driver behavior are missing from the model?

For detailed “Adventures in Calibration”: Dta.googlecode.com Webinar Presentation Slides 25-29
### Data sources for parameter estimation

<table>
<thead>
<tr>
<th>Param.</th>
<th>Free-flow Speed</th>
<th>Saturation Flow</th>
<th>Response Time</th>
<th>Jam Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>FT</td>
<td>PeMS</td>
<td>PeMS</td>
<td>PeMS</td>
<td>Inferred from CBD arterials</td>
</tr>
<tr>
<td>Arterials</td>
<td>SFMTA speed surveys</td>
<td>CBD saturation headway observations</td>
<td>CBD queue dissipation observations</td>
<td>CBD arterial queue length observations</td>
</tr>
<tr>
<td>Locals &amp; Collectors</td>
<td>Limited SFMTA speed surveys &amp; supplemental observations</td>
<td>Mostly inferred from CBD arterials</td>
<td>Mostly inferred from CBD arterials</td>
<td>Mostly inferred from CBD arterials</td>
</tr>
</tbody>
</table>

*Red text = data limitations*
Final Calibration Parameters

- Final generalized cost expression
  - Travel Time, Tolls, Turn Penalties
  - Distance tried, didn’t work well
- Response times
  - Function of uphill and downhill slopes
- Signalized turning movement capacity:
  - Function of asserted pedestrian densities
- Read all about the details:
  
  http://www.sfcta.org/dta

Additional reading material!
Validation Data - Counts

- Count Dracula is SFCTA’s traffic counts database
- Recent (2009-2011) midweek (Tue/Wed/Thu) counts queried from Count Dracula API for DTA Validation

<table>
<thead>
<tr>
<th></th>
<th>Counts</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-minute link</td>
<td>97</td>
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<tr>
<td>60-minute link</td>
<td>22</td>
</tr>
<tr>
<td>15-minute movement</td>
<td>864</td>
</tr>
<tr>
<td>5-minute movement</td>
<td>160</td>
</tr>
</tbody>
</table>

For more CountDracula
Lisa Zorn presents: “Sharing Is Caring”
Wednesday, 1:30 PM

https://github.com/sfcta/CountDracula
Validation Data – Travel Times

- Spring 2011 Level of Service Monitoring
- 272 Summary Segments
Validation Results
Convergence & Performance

- DTA shows stable convergence for ~20 iterations
- Mean Relative Gap: 2.7%
- 109 50ish hours computing
- Max waiting vehicles ~ 350 (1%)
- Demand clears in reasonable time
- No observed gridlock
Validation Results

Link Volumes

- Total volume ~13% low.
- What are some good standards? We couldn’t find any and neither could our peer review panel.
- 55% total RMSE, 40% RMSE for links >500 vph.
- 75% of arterials within Caltrans maximum desirable deviation guidelines
Validation Results
Segment Travel Times

- Travel times are reasonable on average
- A few outliers drive differences

Observed vs. Simulated Travel Times

\[ y = 0.9985x \]

\[ R^2 = 0.57527 \]
Validation Results
Citywide Flow Patterns

- Overall flow pattern logical, and similar to static model

Map of Total PM Peak Flow from DTA

Map of Total PM Peak Flow from Static Assignment
SENSITIVITY & SCENARIO TESTING

Random Number Seeds
Small Network Change
Future Demand
Congestion Pricing
Bus Rapid Transit
Added a $3 fee to anyone crossing the cordon to manage congestion in downtown San Francisco
Congestion Pricing Application Test – Static vs. DTA Flow Maps

- DTA Model shows a much clearer diversion to paths outside the cordon
- Static model shows some odd shifts that in the Northern region including increases in EB traffic going toward the CBD

Map of Flow Change from Static Pricing Test (Red links – flow loss of at least 250 vehicles, Blue links – flow gain of at least 250 vehicles)

Map of Flow Change from DTA Pricing Test (Red links – flow loss of at least 250 vehicles, Blue links – flow gain of at least 250 vehicles)
Congestion Pricing Application Test – Static vs. DTA Speed Maps

- DTA Model shows more widespread impacts on speed with faster speeds in most of the CBD.
- Using the static model results could greatly underestimate the potential travel time impacts in the CBD.

Map of Speed Change from Static Pricing Test (Red links – speed loss of at least 5 mph, Blue links – speed increase of at least 5 mph)

Map of Speed Change from DTA Pricing Test (Red links – speed loss of at least 5 mph, Blue links – speed increase of at least 5 mph)
Credit where it is due...

**SFCTA**
- Elizabeth Sall – Conductor
- Lisa Zorn – Code Cowgirl
- Daniel Tischler – Calibration Hero
- Neema Nassir – Traffic Model Data Collection Dynamo
- John Urgo – Willing data collector
- Annie Chung & Matthew Chan – Courageous count coders

**Parsons Brinckerhoff**
- Gregory Erhardt – Consultant PM
- Renee Alsup – Calibration Hero
  [Michalis Xynatarakis] – the one who had done this before
- Jim Hicks & Joel Freedman – Parental Supervision

**Peer Review Team**
- Joe Castiglione
- Bruce Griesenbeck
- Vassilis Papayannoulis
- David Stanek
- Xuesong Zhou

**Keeping Us Sane**
- Michael Mahut – INRO
- Brian Gardner – FHWA

www.sfcta.org/dta  dta.googlecode.com
Credit where it’s due….

Greg Erhardt (PB) – Consultant PM
Lisa Zorn (SFCTA) – Codebase Lead + CountDracula
Daniel Tischler (SFCTA) – Traffic Flow Calibration Lead
Renee Alsup (PB) – Calibration + Sensitivity Testing
Neema Nassir (SFCTA/U of Arizona) – Traffic Flow Model
Michalis Xyntarakis – Early codebase development

www.sfcta.org/dta    dta.googlecode.com
Traffic Flow Parameter Measurement

Space

Red Light

Saturation Flow

Backward Shockwave

EL

H

RT

Time
FUTURE WORK & ONGOING RESEARCH
Future Work: Deployment

- Examine stochasticity
  - Useful tool for finding ranges
- Work with local consultants and agencies
- Use with real projects!
Future Work: Development

- Improve pedestrian/bike interaction representation
- Represent actual parking locations
- Improve demand in SF-CHAMP
Research: Person-based Transit Assignment

FAST-TrIIPs

**FAST-TrIIPs**
Simulate individual riders, individual buses based on DTA trajectories (or GTFS)

**DTA**
Update transit vehicles’ dwell time f(FAST-TrIIPs boarding and alightings)

**Why?**
- Bus Bunching
- Transit reliability
- Capacities
- Actual schedules

See: Khani, Zorn and Sall, 2013 TRB Annual Meeting
Research: Person-based Transit Assignment

FAST-TrIPs

Route 38 - Geary Blvd, Vehicle Trip Starting at 5:47PM

See: Khani, Zorn and Sall, 2013 TRB Annual Meeting
Research: Transit Reliability / FAST-TrIPs Development

- More FAST-TrIPs/DTA Integration
  - Convergence methodologies
- FAST-TrIPs/CHAMP Integration
  - Use static assignment
  - Skimming
  - Sensitivity tests
- Develop Reliability Metrics in FAST-TrIPs
  - As function of demand profiles
  - As function of network and service characteristics
Convert Static Network → Dynamic

1. Define Scenario: vehicle types and classes, generalized cost
2. Import Cube network data, defining DTA attributes in terms of Cube attributes
3. Add all movements, prohibiting most U-Turns, explicitly naming some where geometry is confusing
4. Read GIS shapefile for road curvature
5. Add virtual nodes/links between centroids and road nodes
6. Move centroid connectors from intersections to midblock

SAN FRANCISCO COUNTY TRANSPORTATION AUTHORITY

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Nodes</td>
<td>15,000</td>
</tr>
<tr>
<td>Links</td>
<td>37,000</td>
</tr>
<tr>
<td>Movements</td>
<td>109,000</td>
</tr>
</tbody>
</table>
Import Transit Routes

1. Reads Cube-formatted transit line files and converts into DTA transit lines
2. Use shortest-path to connect links that may have been split
3. Where LRT lines go off the DTA network (underground or on separated ROW), they are split into segments (discarding those not on the DTA network)
4. Movements are explicitly allowed for transit if previously prohibited

236 Transit Lines
Import Signals

- Reads signal card data from Excel files in a SFMTA-defined format
- We search for the section specifying the weekday PM peak plan
- For errors and unique circumstances encountered (and there were many), responses could be:
  - Update signal card itself
  - Update signal-card reading code
  - Update static network
- We approximate the few actuated signals with their fixed time version
- Signal-reading code is not very reusable

1,100 Signal Time Plans
Import Stop Signs

- Stop signs are coded as (GIS point, street name, cross street name, and direction the stop sign is facing)
- Signal data takes precedence
- Mark as all-way stops when # of stop signs for a node matches the # of incoming links
- Otherwise, mark as two-way

<table>
<thead>
<tr>
<th>Count</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,845</td>
<td>All-way stop nodes</td>
</tr>
<tr>
<td>919</td>
<td>Two-way stop nodes</td>
</tr>
<tr>
<td>1,020</td>
<td>Custom priority stop nodes</td>
</tr>
</tbody>
</table>
Import Demand

- Auto and truck tables are imported from SF-CHAMP MD, PM, EV demand tables
  - 535.2k auto trips, 84.2k truck trips loaded 2:30-7:30p
- The DTA network uses same TAZ structure is used as SF-CHAMP because the zones are small (976 within SF, plus 22 external stations)
- The PM (3:30p-6:30p) demand is peaked slightly towards 5-6p based on traffic counts
Future Work - Development

Level of Effort

Low Effort

Near Term

3.1 Investigate Stability

2.1 Transit Representation (Transit Lanes)

2.2 Non-Motorized Representation

Potential Schedule

Long Term

2.3 Robust Parking Model

2.5 Truck / Commercial Vehicle Model

4.3 Dynamic Skims

4.3 Temporal Robustness

High Effort

2.1 Transit Representation (FAST-TriPs)

4.2 24-Hour DTA

3.2 Computing Efficiency

4.1 Reliability Variables

Integrated SF-CHAMP / SF-DTA Model