San Francisco's Dynamic Traffic Assignment Model

(& the DTA Anyway Library)



SAN FRANCISCO COUNTY TRANSPORTATION AUTHORITY

Final Project Webinar November 30, 2012

The DTA Model Development Team

<u>SFCTA</u>

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<u>Keeping Us Sane</u> Michael Mahut – INRO Brian Gardner – FHWA



Why DTA?

Better representation of the real world

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



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Less messy spreadsheet work

- Less subjectivity
- Fewer typos/errors



An additional tool in the toolbox - DTA



Regional static user equilibrium within an activity-based model

Time-dependent user equilibrium with realistic, but simplified vehicle simulation

Traffic Microsimulation



Highly realistic simulation of vehicle behavior and interactions



Spatial Detail in SF-CHAMP

Every transit stop Every transit line Every street Every Hill

981 Zones in SF



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



DTA ANYWAY CODEBASE & NETWORK DEVELOPMENT

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DTA Anyway Capabilities

DTA Anyway Can

- Read Cube Networks or other text-based static networks
- Read/Write Dynameq
 ASCII files
- Write GIS shapefiles for nodes, links, movements
- Perform typical network editing tasks (e.g. find the link nearest a point, split a link)

DTA Anyway Cannot

- Visualize anything directly (no GUI) – use GIS, or traffic assignment network editor (Static or DTA)
- Read/Write DTA networks for other DTA software (but designed to make this easily implementable)





DTA Anyway for Automation





Convert Static Network \rightarrow Dynamic

- 1. Define Scenario: vehicle types and classes, generalized cost
- 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 nodes
- 7. Handle overlapping and short links









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

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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



1,100 Signal Time Plans

- We approximate the few actuated signals with their fixed time version
- Signal-reading code is not very re-





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

- **1,845** All-way stop nodes
 - 919 Two-way stop nodes
- **1**,020 Custom priority stop nodes
- Custom priorities for two-way stops where facility types tie



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



Import Counts

- Count Dracula is SFCTA's developing traffic counts database
- Includes counts from PEMS and counts collected for past projects
- Recent (2009-2011) midweek (Tue/Wed/Thu) counts are queried from Count Dracula for DTA Validation
- When multiple days of counts exist for the same location and time period, averaged across days
 - https://github.com/sfcta/CountDracula

- 97 15-minute link counts
- 22 60-minute link counts
- 864 15-minute movement counts
- **160 5-minute movement counts**





CALIBRATION AND VALIDATION

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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?



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Dynameq Representation of Traffic Flow

Triangular fundamental diagram



- PeMS data provides observed freeway flow-density relationships
- Piece-wise linear curves extracted from scatter plots
 - ► 59 SF freeway lanes considered (30 used)
 - **Estimated free-flow speed, backwards wave speed, and saturation flow**



- Local streets and arterial parameter estimation
 - Existing data

Speed surveys of free-flow speed

Collected data (from queue dissipation)

Vehicle type (car, truck, bus, motorcycle) Front bumper distance from stop bar (EL) Time when vehicle begins to move (RT) Time when vehicle passes stop bar (H) Approximate slope of street







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Data sources for parameter estimation

Param. FT	Free-flow Speed	Saturation Flow	Response Time	Jam Density
Freeways	PeMS	PeMS	PeMS	Inferred from CBD arterials
Arterials	SFMTA speed surveys	CBD saturation headway observations	CBD queue dissipation observations	CBD arterial queue length observations
Locals & Collectors	Limited SFMTA speed surveys & supplemental observations	Mostly inferred from CBD arterials	Mostly inferred from CBD arterials	Mostly inferred from CBD arterials



Red text = *data limitations*

Adventures in Model Calibration Resolving Chokepoints

- In this example, SB traffic on Battery St backs up crossing Mission St, causing gridlock throughout downtown
- Issue related to the timing of the signal at that intersection





Adventures in Model Calibration Locals & Collectors

- Early results showed DTA predicted higher traffic on local grid network
- What's wrong?
 - Most intersections are stop-controlled and model not fully accounting for lost time due to acceleration & deceleration
 - ► Perceived TT ≠ experienced TT
- Intervention
 - Reduced free-flow speed as proxy for acceleration & deceleration lost time
 - Added ½ of free-flow travel time to generalized cost expression



Locals and collectors in blue shades







Adventures in Model Calibration

Bus Lanes

- Changing bus lane restrictions resulted in large change in congestion
 - Full bus lanes cause gridlock
 - Ignoring bus lanes adds
 "fake" capacity
- Modeled using a link-splitting approach to approximate real world lane permissions







Adventures in Model Calibration Pedestrian Friction

- Pedestrian-auto conflicts are an important source of delay in downtown San Francisco
- Approach
 - SFMTA ped counts at 50 locations
 - ► HCM 2010 → turning movement saturation flow adjustment factors
 - Adjust turn movement follow-up time
 - ► Test and refine parameters





Thank you batchgeo.com





Adventures in Model Calibration Freeway Lane Changes

- Freeway merge, diverge, and weave sections
 - Excessive last minute lane changes reduce segment capacity on NB US-101
 - Creates unrealistic backups and delay
- Approach
 - Real world driver behavior more aggressive in these situations
 - Reduce response time on problem link \rightarrow improves assignment results





Final Parameters

After much trial-anderror, we have a set of traffic flow parameters that works well

Length, Speed, and Response Time

Factor \ Vehicle Class	Car	Truck
Effective Length (ft)	21	31.5
Effective Length Factor	1.0*	1.0*
Maximum Speed (mph)	100	70
Vehicle Type Response Time (s)	1.0	1.25

* Effective length factor is 1.0 throughout most of San Francisco, but it is currently set to 0.95 in and around the San Francisco CBD (defined as area types zero and one (AT0 & AT1).

Saturation Flow Rates

Saturation Flow (vphpl)*	Regional Core	CBD	Urban Biz	Urban
Alley	1,342	1,342	1,342	1,342
Local	1,760	1,760	1,760	1,633
Collector	1,923	1,923	1,831	1,831
Minor Arterial	1,999	1,999	2,044	2,084
Major Arterial	2,044	2,044	2,084	2,121
Super Arterial	2,084	2,084	2,138	2,185
Freeway Ramp	2,084	2,084	2,170	2,170
Fwy-Fwy Connector	2,170	2,239	2,296	2,296
Expressway	2,418	2,449	2,449	2,449
Freeway	2,418	2,449	2,449	2,449

* Saturation flow rates displayed are for flat terrain. Due to differences in the response time factor for grade, uphill streets have slightly lower saturation flow rates and downhill streets have slightly higher saturation flow rates.

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Final Parameters

Final generalized cost expression

GeneralizedCost = Time + LeftTurnPenalty + RightTurnPenalty + FacilityPenalty + TollPenalty where:

LeftTurnPenalty =	30 seconds if left turn
RightTurnPenalty =	10 seconds if right turn
FacilityPenalty =	50% of free flow travel speed if link is
	alley, local or collector
Toll Penalty =	Toll as specified in the scenario

Other final parameters

- Response time: 1s flat +/- 10% uphill / downhill
- Signalized turning movement capacity:

1,620/hr in CBD 1,710/hr near CBD 1,800/hr elsewhere San Francisco Dynamic Traffic Assignment Project "DTA Anyway" Final Methodology Report Prepared by: Parsons Brinckerhoff and San Francisco County Transportation Authority November 28, 2012 San Francisco Dynamic Traffic Assignment Project Final Methodolory Report

Additional reading material!



Validation Results Convergence & Performance



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Validation Results Link Volumes

- ► Total volume ~13% low.
- ▶ 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 Travel Time (mins)



Observed vs. Simulated Travel Times

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

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Map of Flow Change for Random Seed test from 5:00 to 6:00 pm (Red links – flow loss of at least 100 vehicles, Blue links – flow gain of at least 100 vehicles)

Map of Speed Change for Random Seed test (Red links – speed decrease of at least 5 mph, Blue links – speed increase of at least 5 mph)



Small Network Change Test

- for 5 blocks
- Removed 1 lane in each direction from Sunset Blvd for 5 blocks between Taraval and Ortega
- Area is generally low-volume, so there shouldn't be much change



Map of Flow Change for Network Change test from 5:00 to 6:00 pm (Red links – flow loss of at least 100 vehicles, Blue links – flow gain of at least 100 vehicles) Map of Speed Change for Network Change test (Red links – speed decrease of at least 5 mph, Blue links – speed increase of at least 5 mph)



Future Demand Test

- Relative Gaps car_notal not yet converged!
- Used 2040 demand levels from SF-CHAMP with 2012 base network
- Car trips increased by 21% and truck trips stayed about the same



Map of Flow Change for 2040 Demand test from 5:00 to 6:00 pm (Red links – flow loss of at least 100 vehicles, Blue links – flow gain of at least 100 vehicles)

Map of Speed Change for Future Demand test (Red links – speed decrease of at least 5 mph, Blue links – speed increase of at least 5 mph)

BRT Application Test

- Added a center-running BRT lane on Mission St in both directions from 14th St to Cesar Chavez St
- Mission went from 2 lanes in each direction to 1 NB auto lane and no SB auto lanes
- South Van Ness went from 2 lanes in each direction to one NB lane and three SB lanes





BRT Application Test – Static vs. DTA Flow Maps

- DTA Model shows much more diversion to adjacent streets
- Flow changes on freeways in the DTA model may be due to stochasticity in the model or to lane-changing and queueing near where Hwy 101 meets Mission and South Van Ness



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



BRT Application Test – Static vs. DTA Speed Maps

- DTA Model shows greater impacts on speed
- Static model shows little change in speed even on links that showed larger changes in flow.



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



Congestion Pricing Application Test

 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)



CONCLUSIONS & LESSONS LEARNED

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Software and Application Process

- Integrated process makes application easier.
- Subarea extraction causes loss of temporal dimension of demand.





Calibration and Validation process

- Matrix estimation is not necessary.
- DTA models are subject to cliff effects.
- A single bottleneck can cause the entire network to become gridlocked.
- A data driven approach provides a valuable starting point.





Sensitivity Testing and Related

- Sensitivity testing is part of calibration.
- Model stochasticity can affect comparisons between scenarios.
- DTA results in more diversion when volume>capacity



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



Future Work - Development



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Future Work - Deployment

- Work with local consultants and agencies
- Use with real projects!



Questions?

www.sfcta.org/dta dta.codegoogle.com



SAN FRANCISCO COUNTY TRANSPORTATION AUTHORITY