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

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

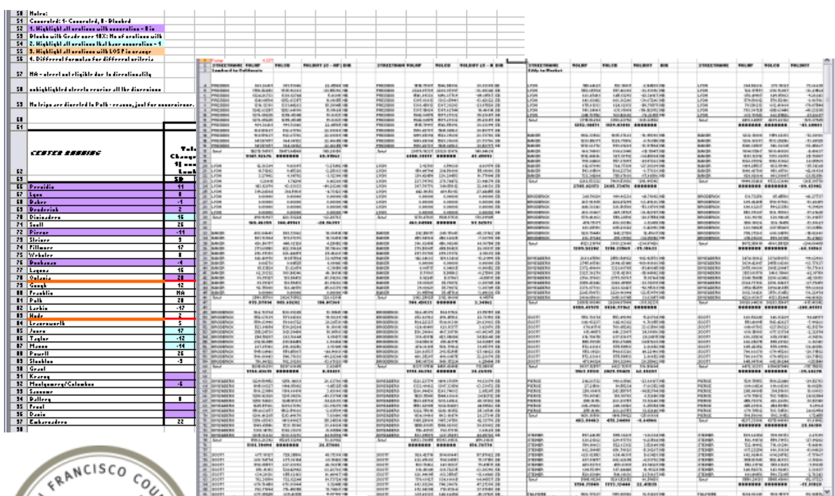
Keeping Us Sane

Michael Mahut – INRO
Brian Gardner – FHWA

Why DTA?

Better representation of the real world

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

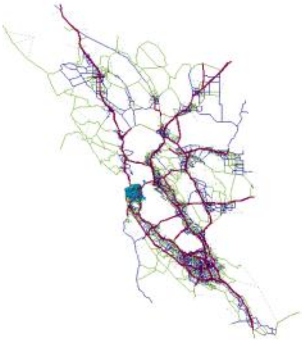


Less messy spreadsheet work

- 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

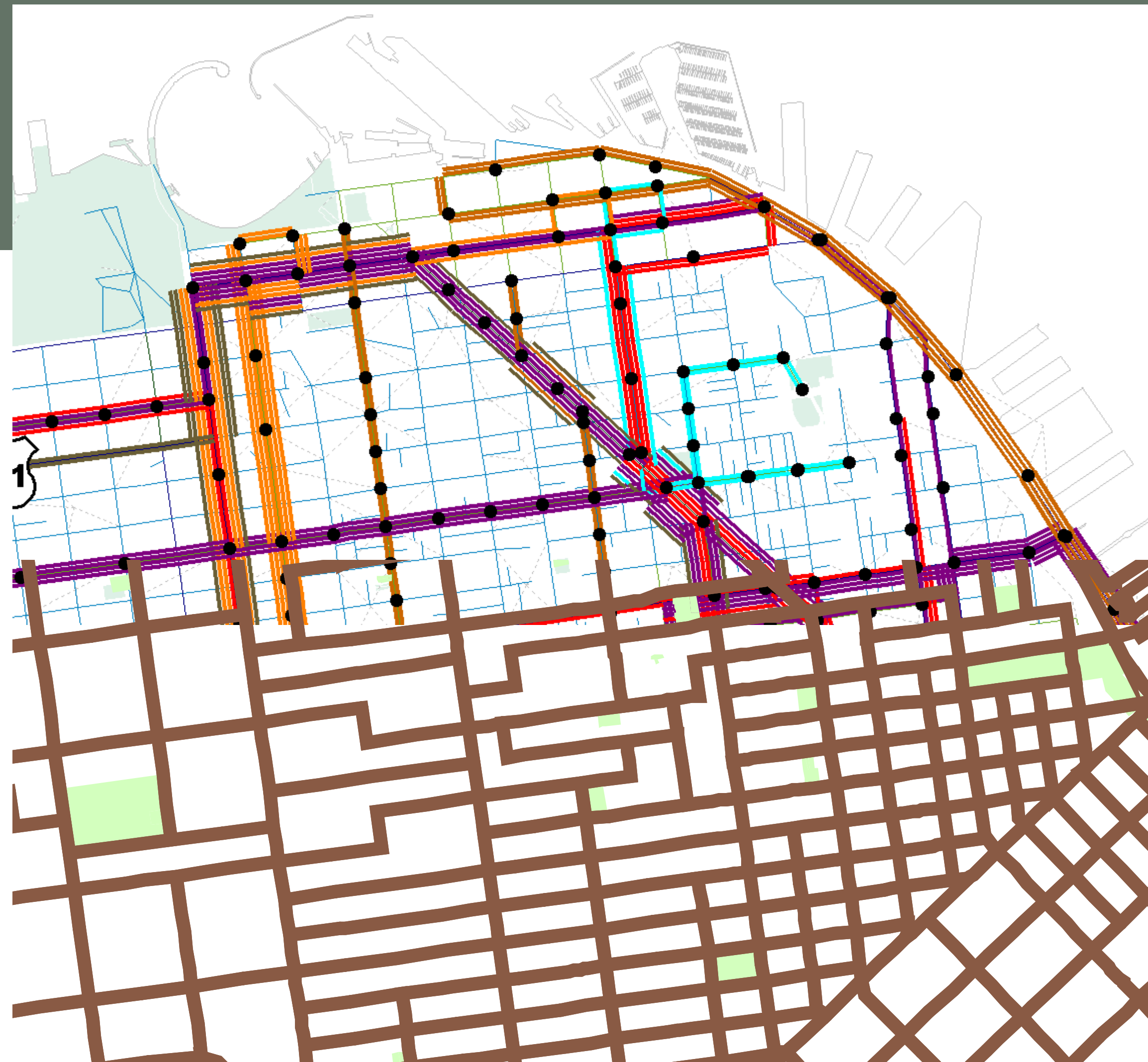
Spatial Detail in SF-CHAMP

Every transit stop

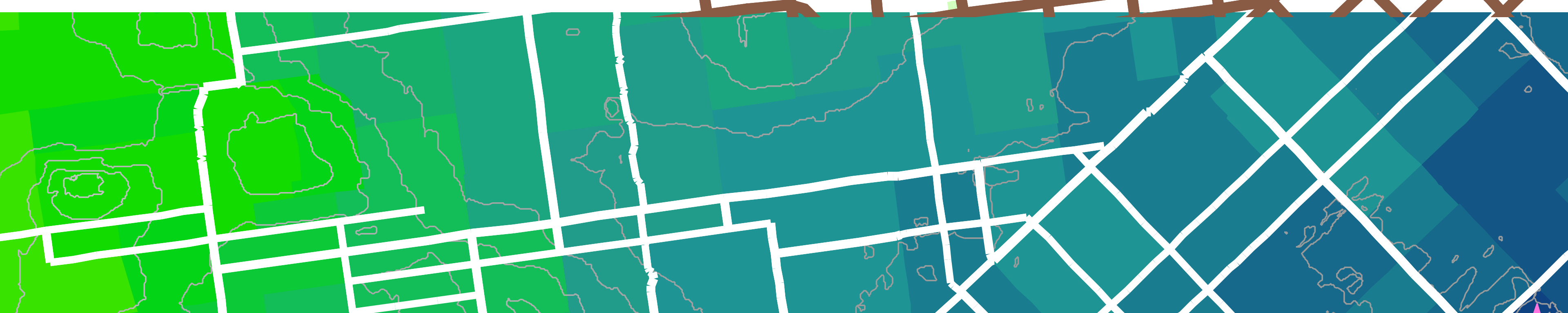
Every transit line

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

Lisa Zorn – Lisa [at] sfcta [dot] org

DTA Anyway Capabilities

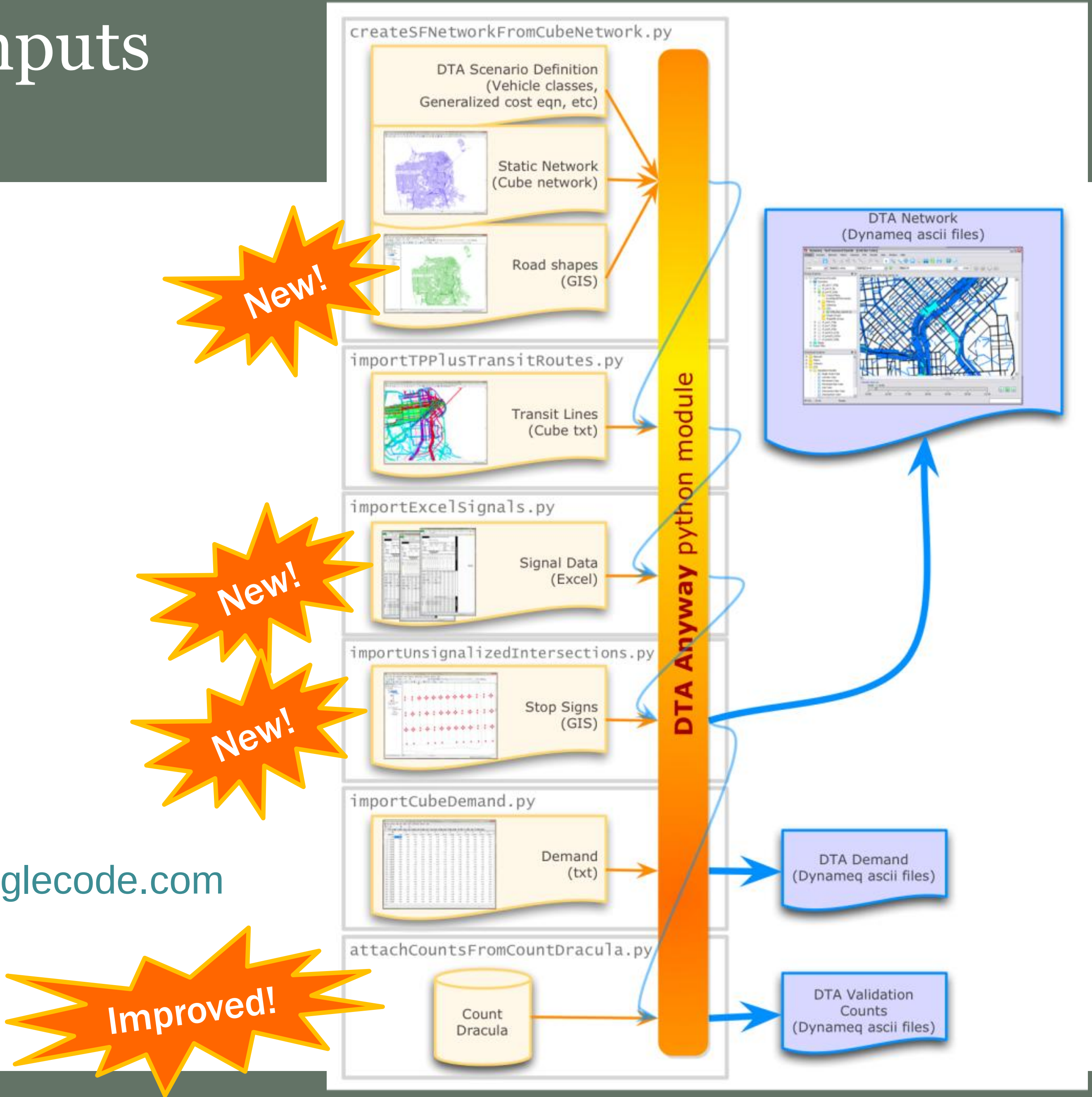
DTA Anyway *Can*

- 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*

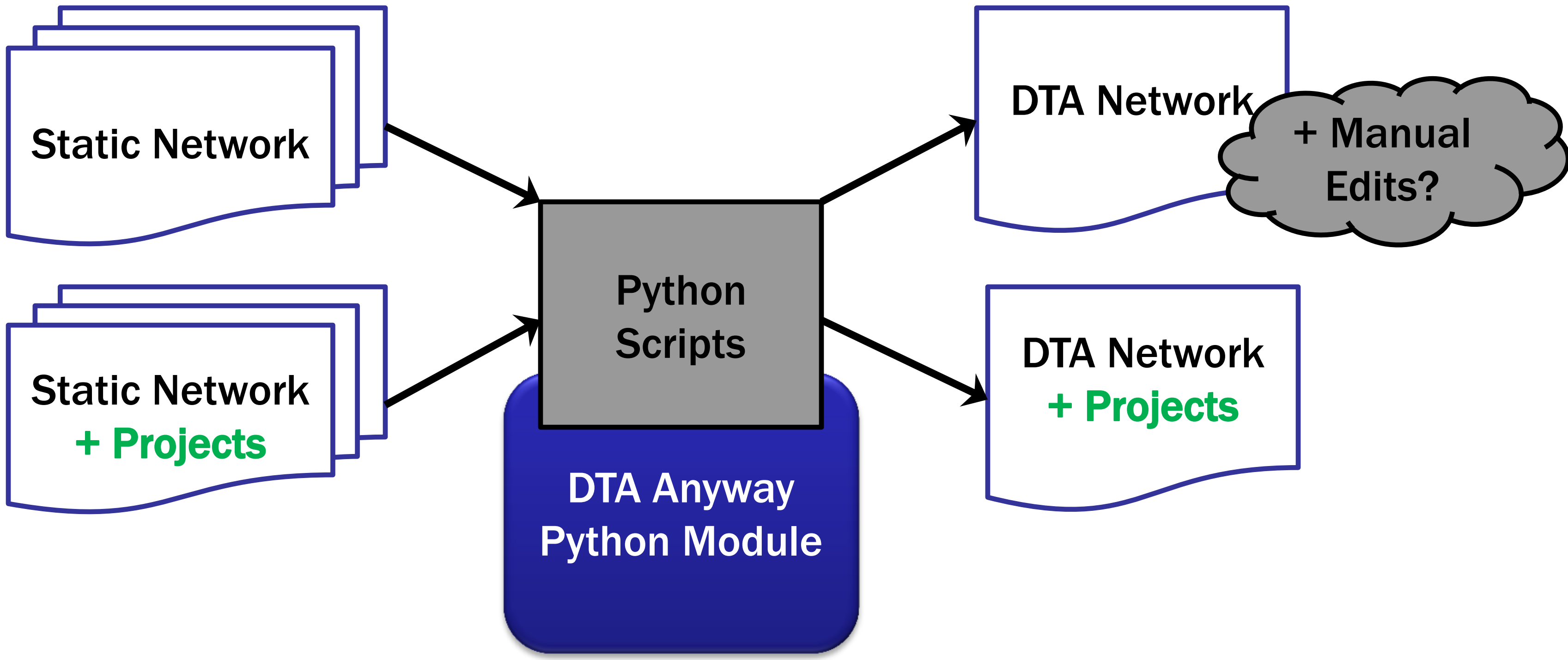
- Visualize anything directly (no GUI) – use GIS, or traffic assignment network editor (Static or DTA)
- Read/Write DTA networks for other DTA software (but designed to make this easily implementable)

DTA Inputs



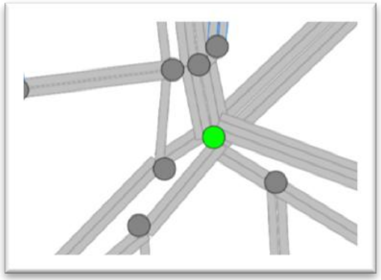
http://dta.googlecode.com

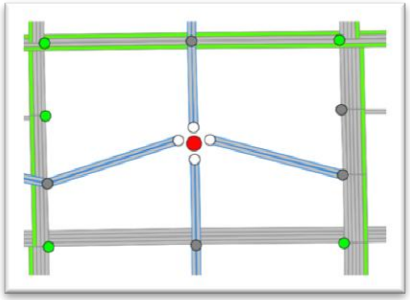
DTA Anyway for Automation

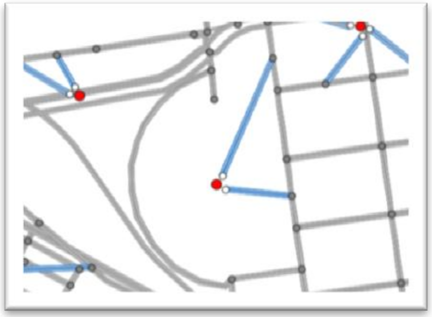


Convert Static Network → Dynamic

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 nodes
7. Handle overlapping and short links







15,000	Nodes
37,000	Links
109,000	Movements

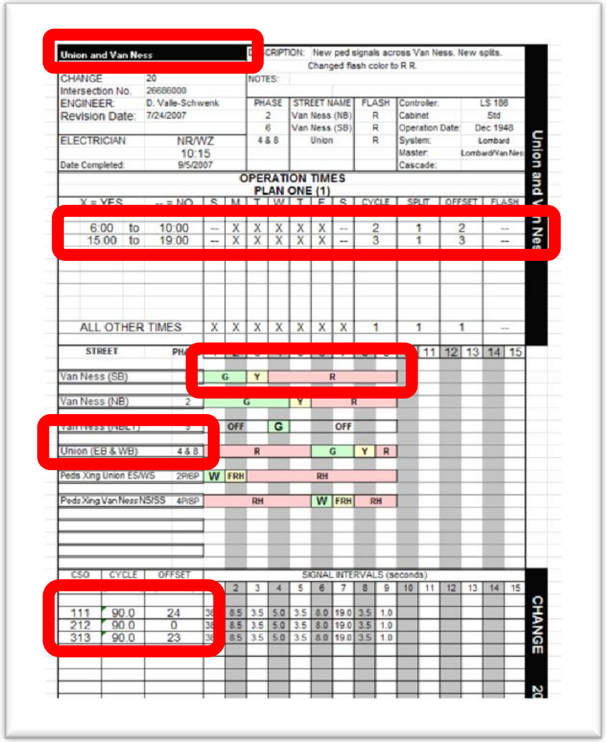
Import Transit Routes

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

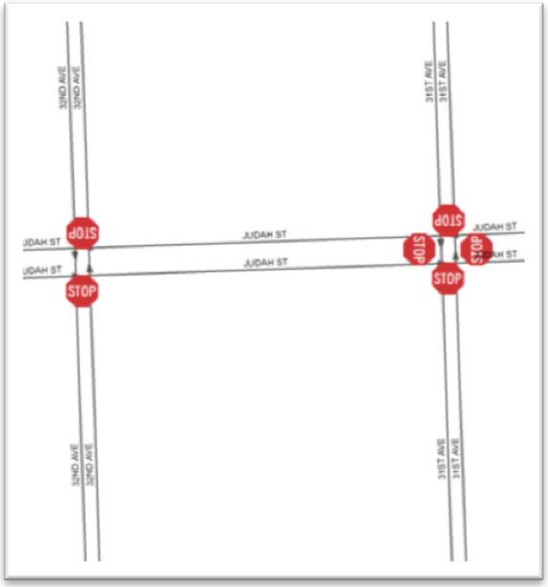
Import Signals

- 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 re-usable



1,100	Signal Time Plans

Import Stop Signs



1,845	All-way stop nodes
919	Two-way stop nodes
1,020	Custom priority stop nodes

- 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

Custom priorities for two-way stops where facility types tie

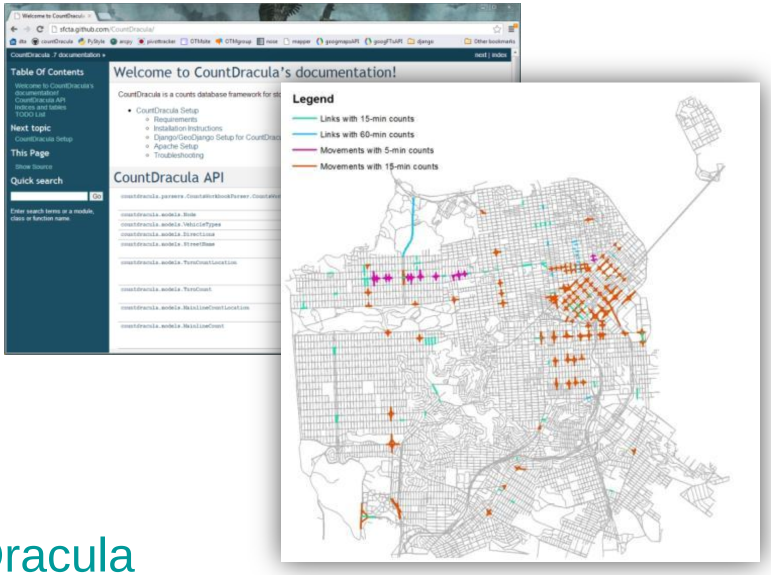
Import Demand

- 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

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



https://github.com/sfcta/CountDracula

CALIBRATION AND VALIDATION

Daniel Tischler – dan [at] sfcta [dot] org

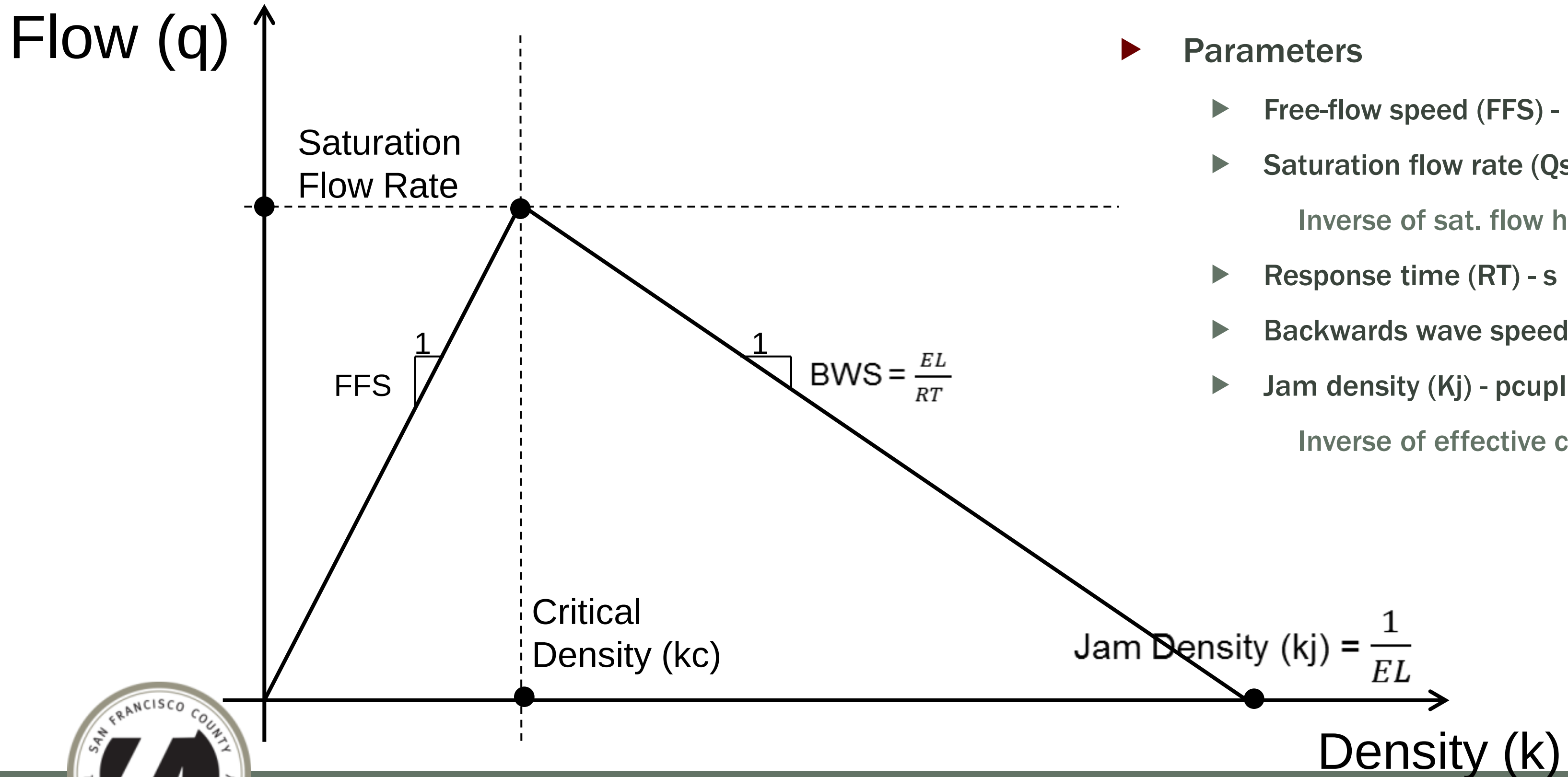
Model Calibration Approach

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?

Traffic Flow Parameter Estimation

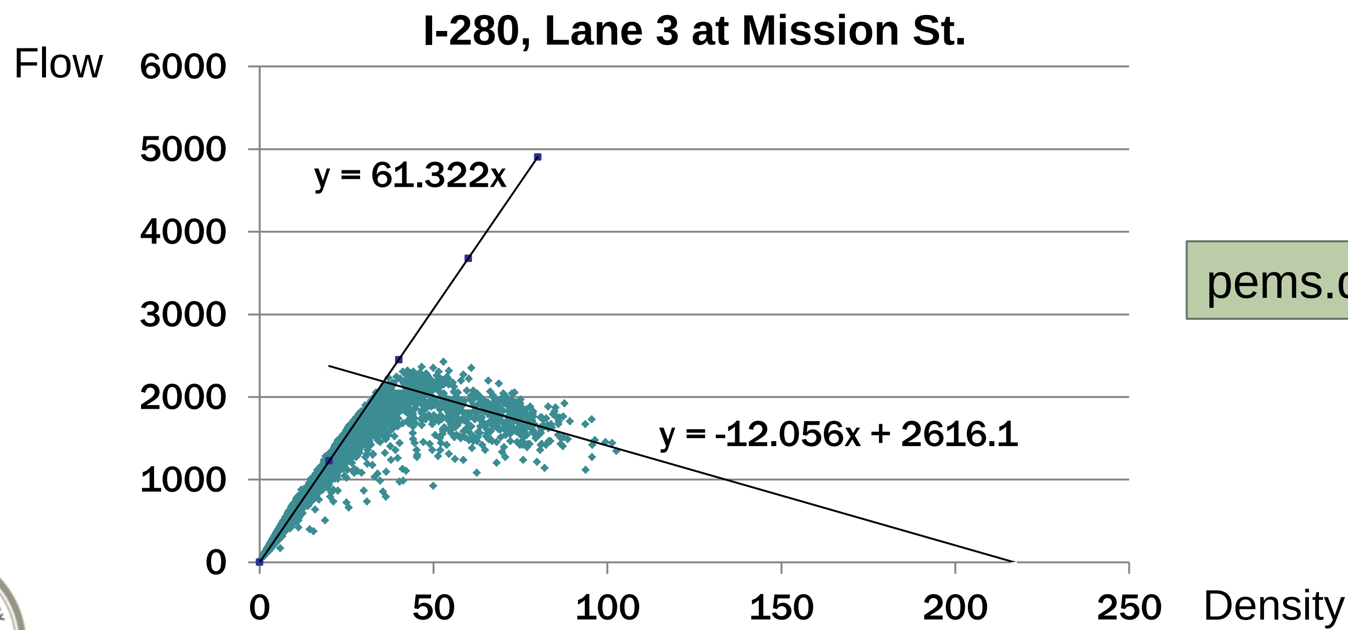
- **Dynameq Representation of Traffic Flow**
  - **Triangular fundamental diagram**



- Parameters
  - Free-flow speed (FFS) - mph
  - Saturation flow rate (Qs) - pcuplph
    - Inverse of sat. flow headway (H) - s
  - Response time (RT) - s
  - Backwards wave speed (BWS) - mph
  - Jam density (Kj) - pcuplpm
    - Inverse of effective car length (EL) - ft

Traffic Flow Parameter Estimation

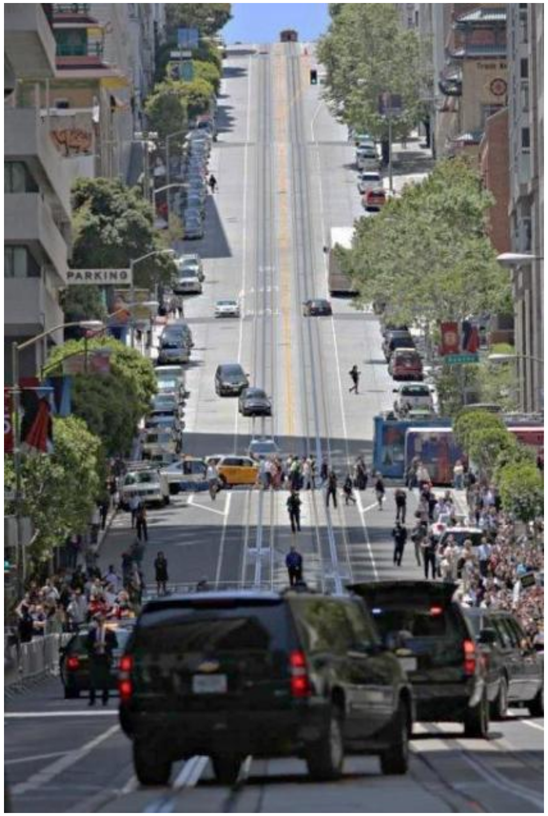
- PeMS data provides observed freeway flow-density relationships
- Piece-wise linear curves extracted from scatter plots
  - 59 SF freeway lanes considered (30 used)
  - Estimated free-flow speed, backwards wave speed, and saturation flow



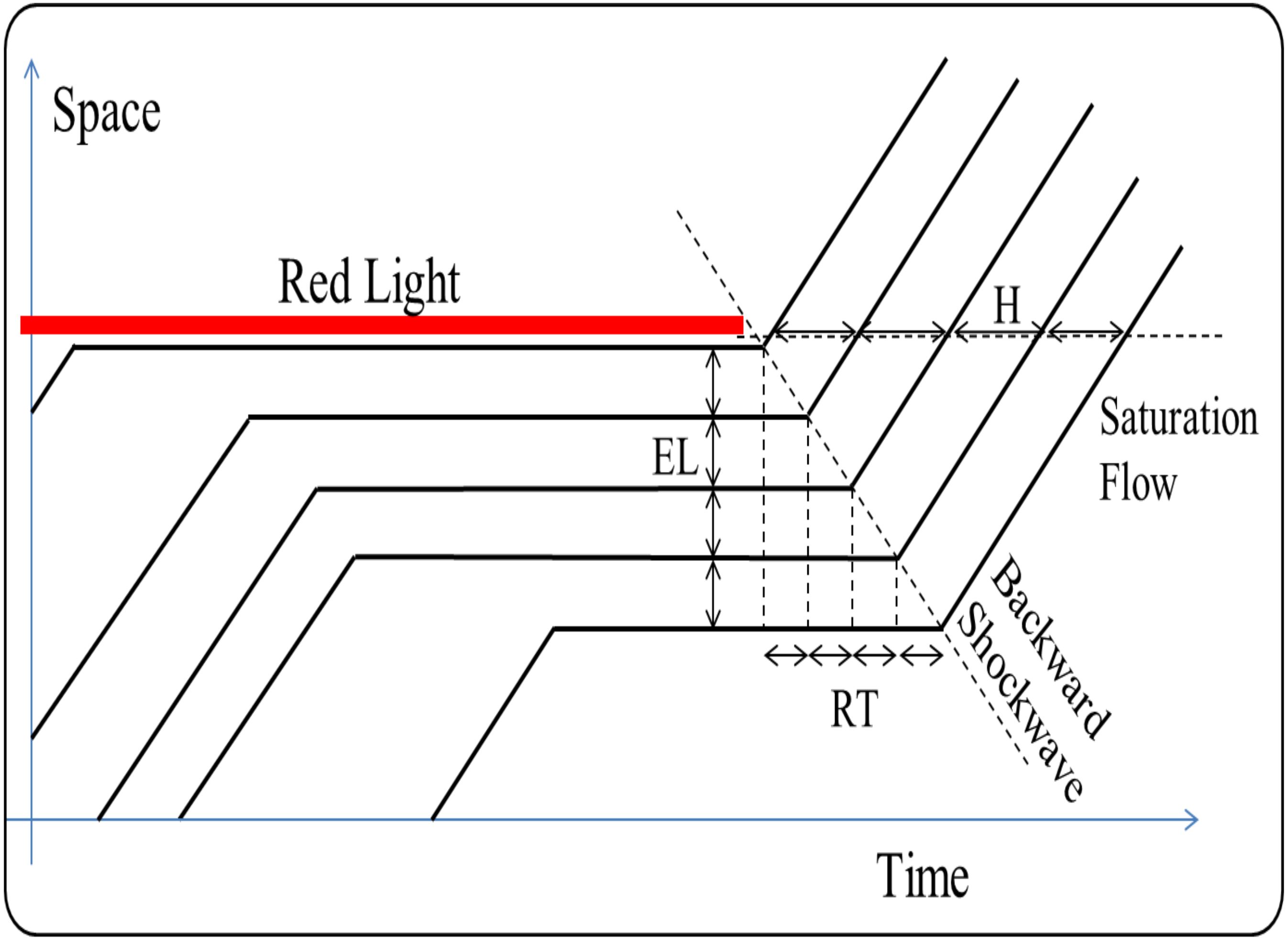
pems.dot.ca.gov

Traffic Flow Parameter Estimation

- **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



Traffic Flow Parameter Estimation



Traffic Flow Parameter Estimation

- 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

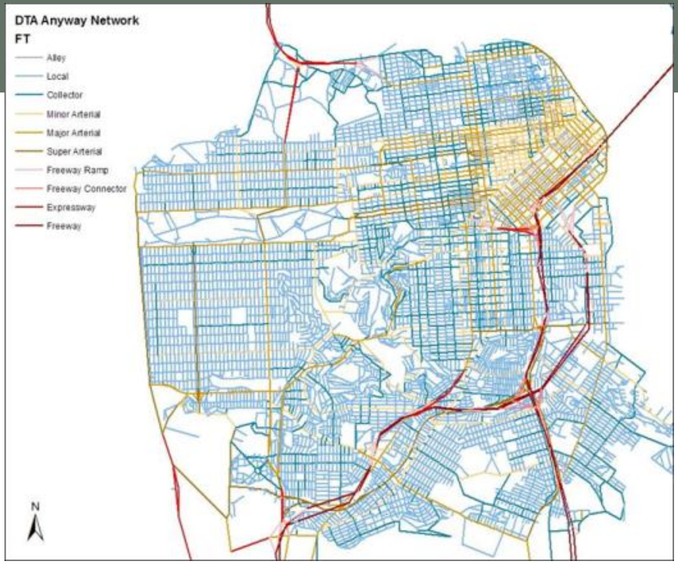
Adventures in Model Calibration Resolving Chokepoints

- 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

In the plot, width of the link represents the link density, and the red color indicates an outflow of less than 5 vehicles per hour

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

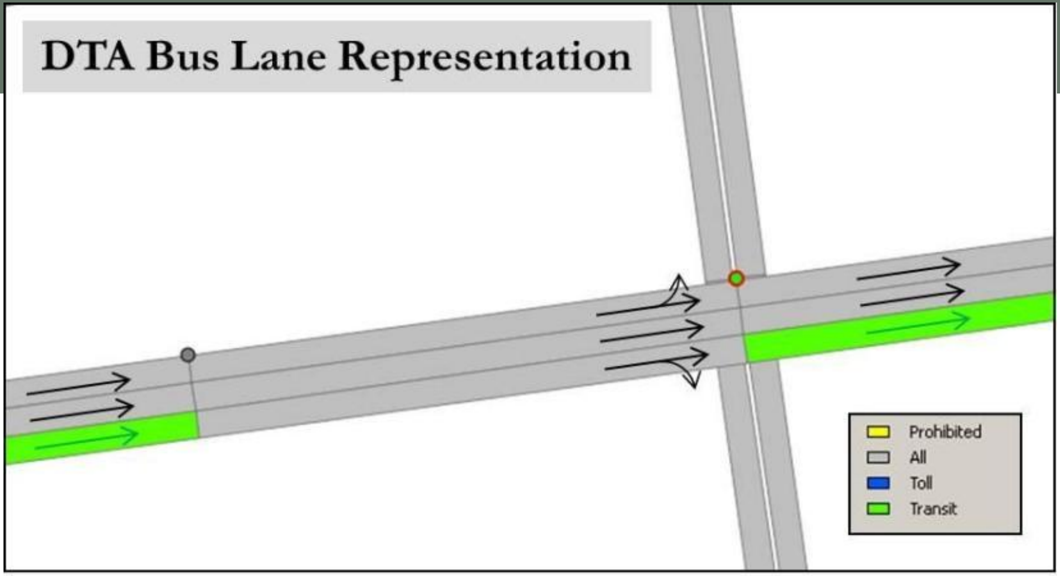


Locals and collectors in blue shades

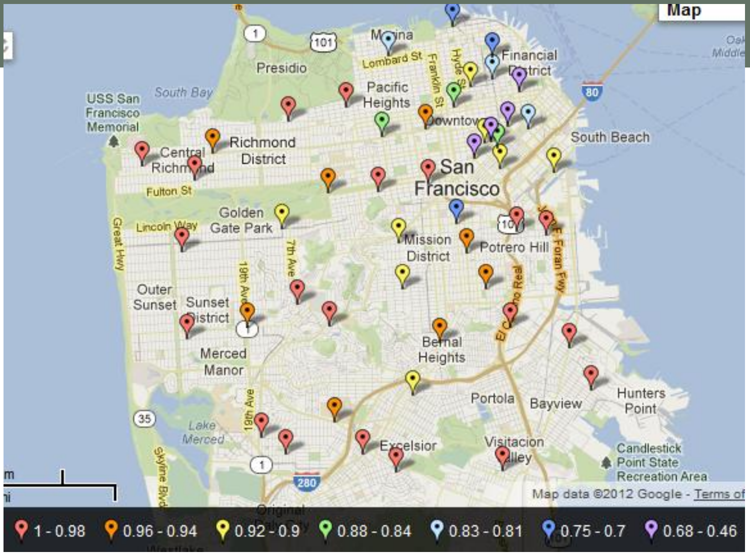
Early Map of Total PM Peak Flow from DTA

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

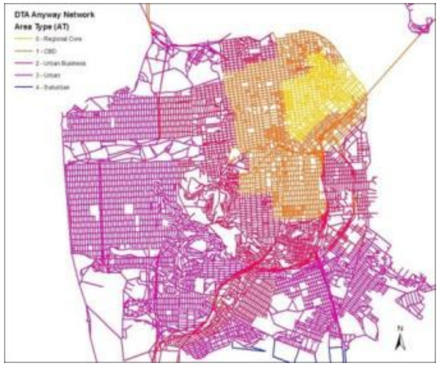


Adventures in Model Calibration
Pedestrian Friction



Thank you batchgeo.com

- 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



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 → improves assignment results

Final Parameters

- After much trial-and-error, 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.

Final Parameters

- **Final generalized cost expression**

GeneralizedCost =	Time + LeftTurnPenalty + RightTurnPenalty + FacilityPenalty + TollPenalty

where:

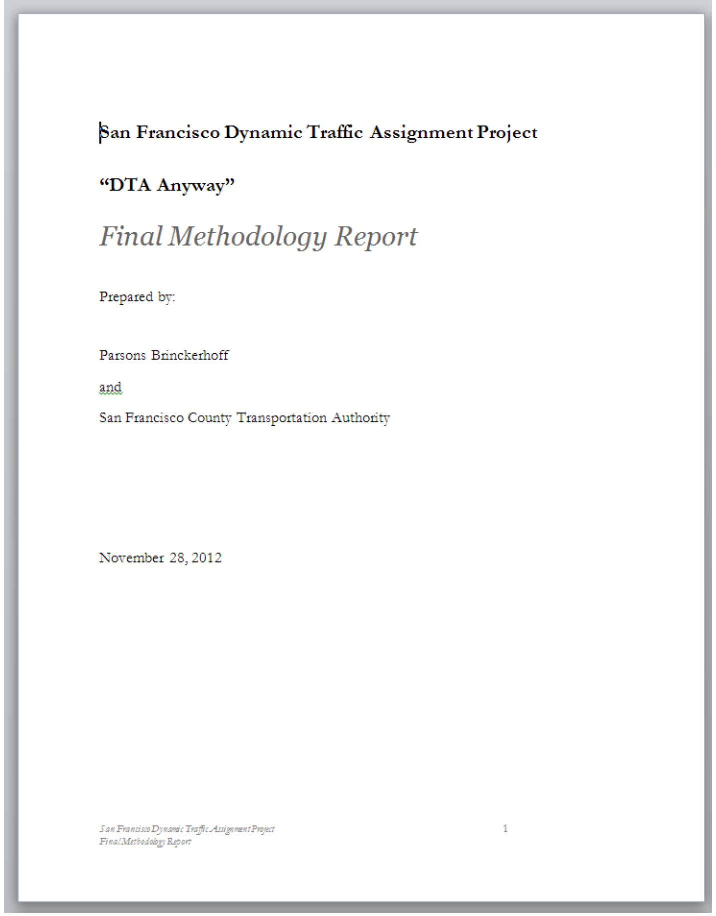
LeftTurnPenalty =	30 seconds if left turn
RightTurnPenalty =	10 seconds if right turn
FacilityPenalty =	50% of free flow travel speed if link is alley, local or collector
Toll Penalty =	Toll as specified in the scenario

- **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

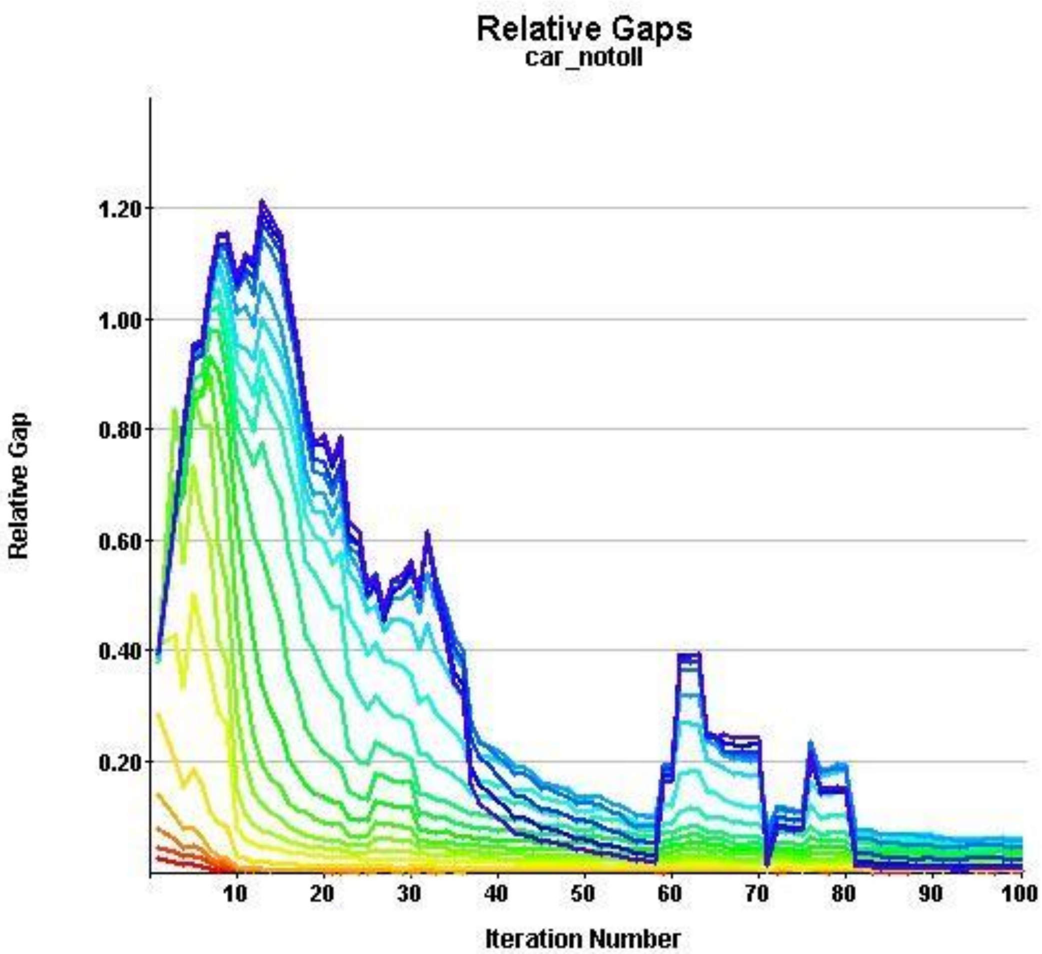
San Francisco County Transportation Authority

November 28, 2012

San Francisco Dynamic Traffic Assignment Project Final Methodology Report 1

Additional reading material!

Validation Results
Convergence & Performance

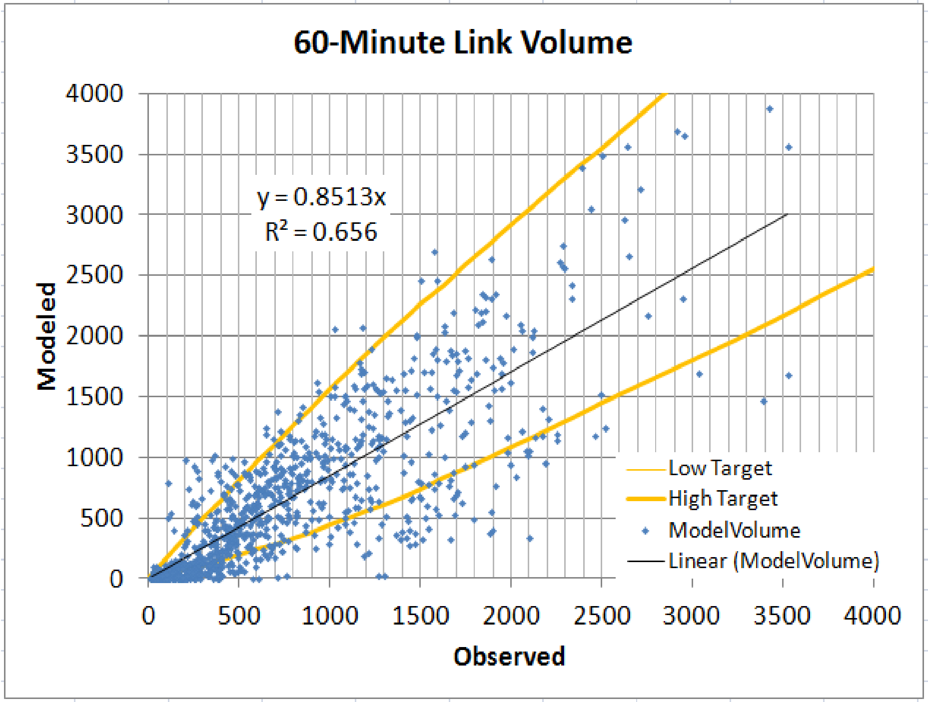


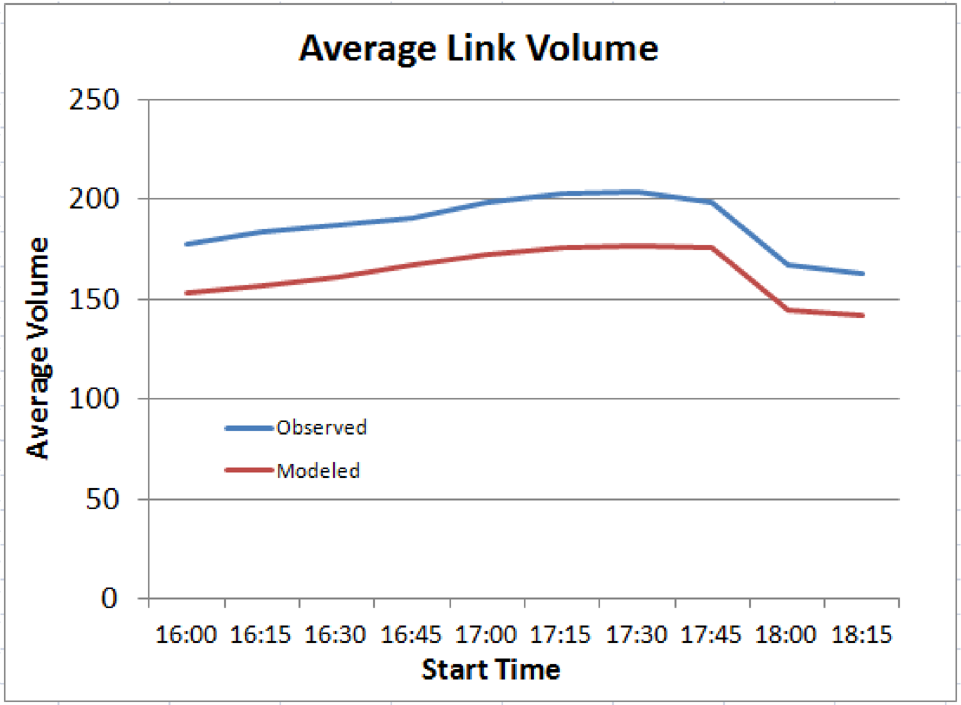
Convergence Plot for Final Model

- DTA shows stable convergence for ~20 iterations
- Mean Relative Gap: 2.7%
- Computing Time:
  - ~52.5 hours w/multi-threading
  - (longer w/RAM swapping, single-thread)
- Max waiting vehicles ~ 350 (1%)
- Demand clears in reasonable time
- No observed gridlock

Validation Results
Link Volumes

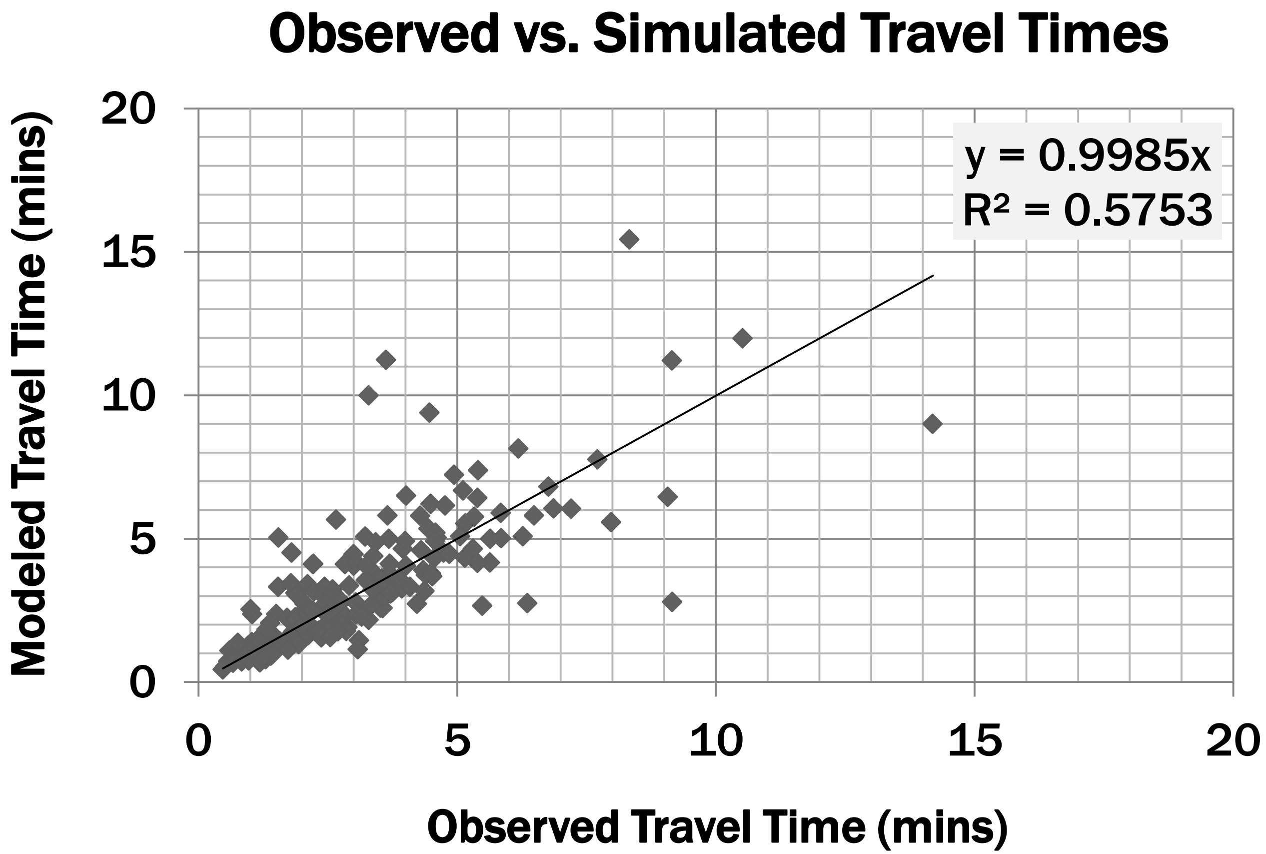
- Total volume ~13% low.
- 55% total RMSE. 40% RMSE for links >500 vph.
- 75% of arterials within Caltrans maximum desirable deviation guidelines





Validation Results
Segment Travel Times

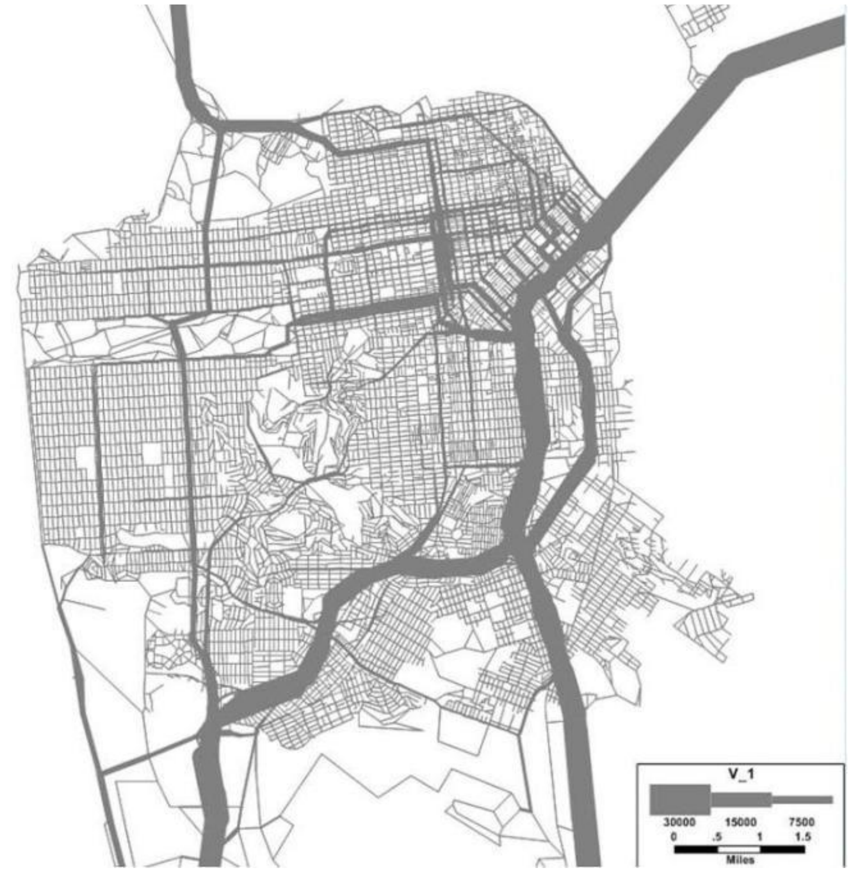
- Travel times are reasonable on average
- A few outliers drive differences



Validation Results
Citywide Flow Patterns

- Overall flow pattern logical, and similar to static model

Map of Total PM Peak Flow from DTA



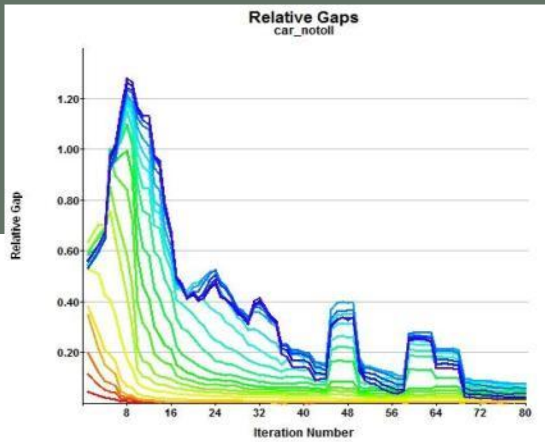
Map of Total PM Peak Flow from Static Assignment

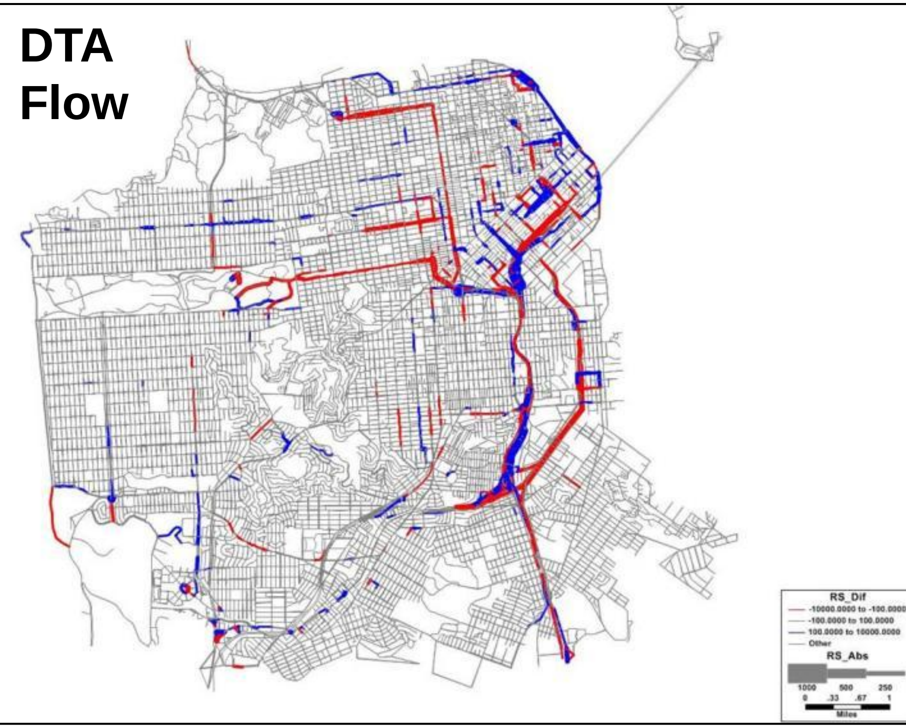
SENSITIVITY & SCENARIO TESTING

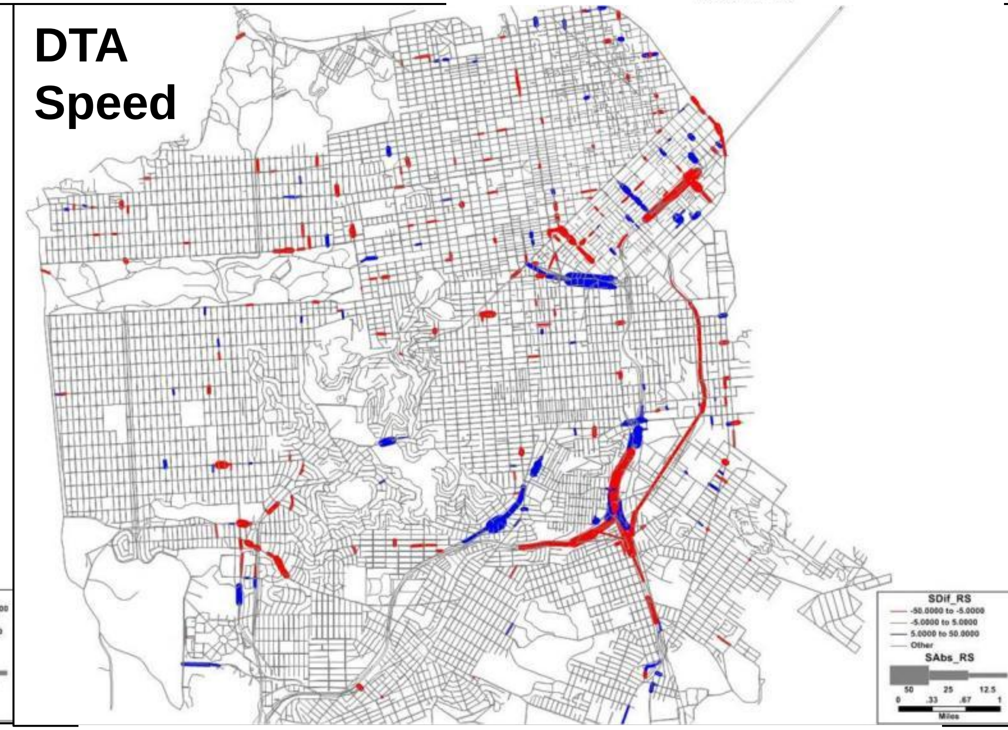
Renee Alsup – alsuprm [at] pbworld [dot] com

Random Seed Test

- Tested Random Seed = 1 vs. Random Seed = 2
- Affects the temporal distribution of trips
  - Bucket rounding



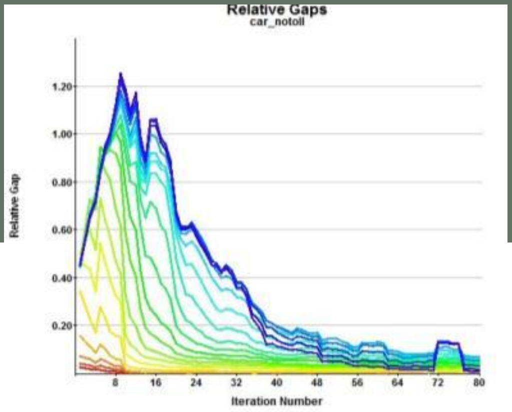




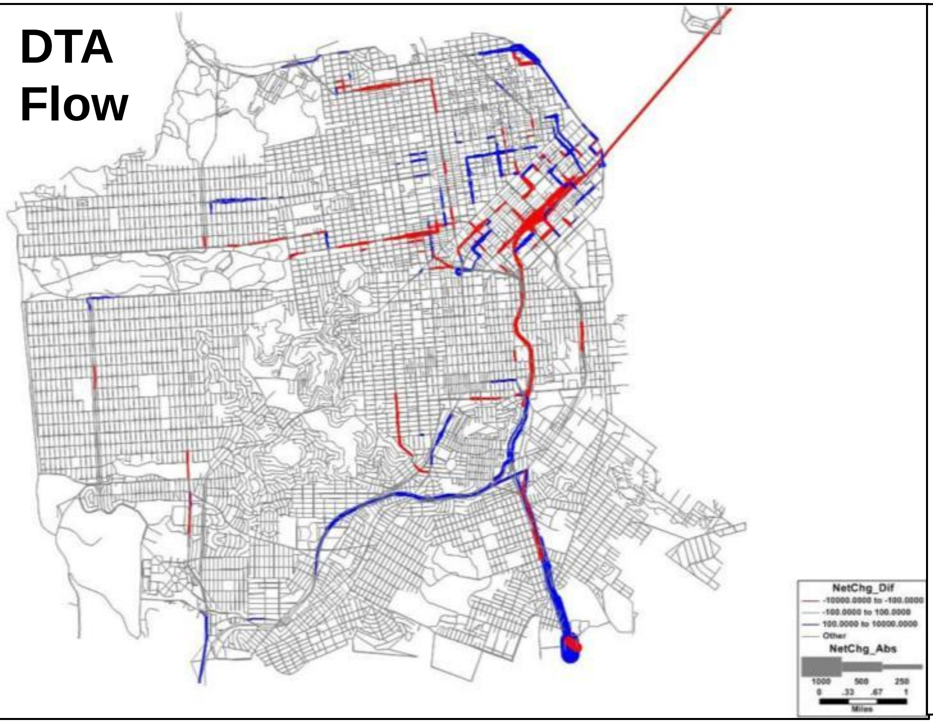
Map of Flow Change for Random Seed test from 5:00 to 6:00 pm (Red links – flow loss of at least 100 vehicles, Blue links – flow gain of at least 100 vehicles)

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)

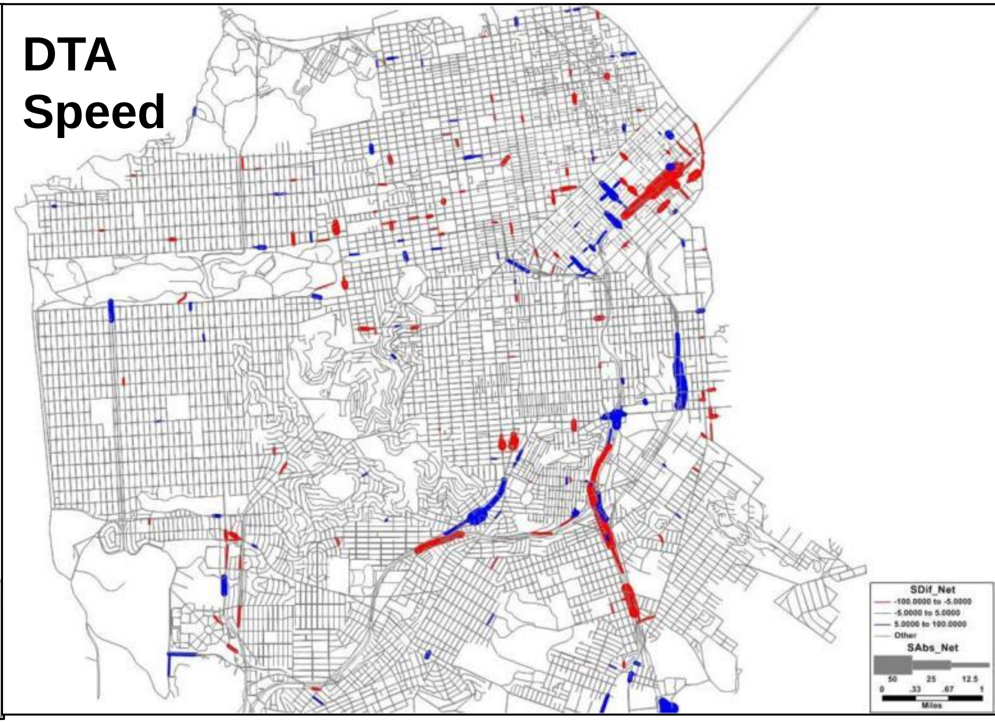
Small Network Change Test



- 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

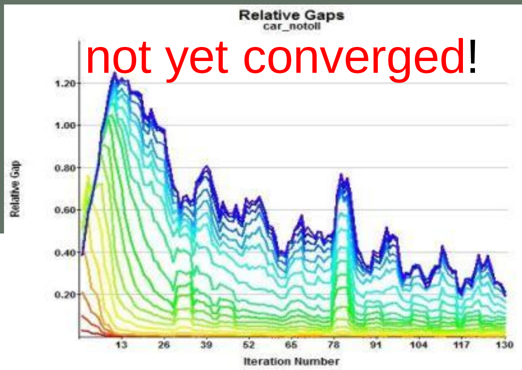


Map of Flow Change for Network Change test from 5:00 to 6:00 pm (Red links – flow loss of at least 100 vehicles, Blue links – flow gain of at least 100 vehicles)

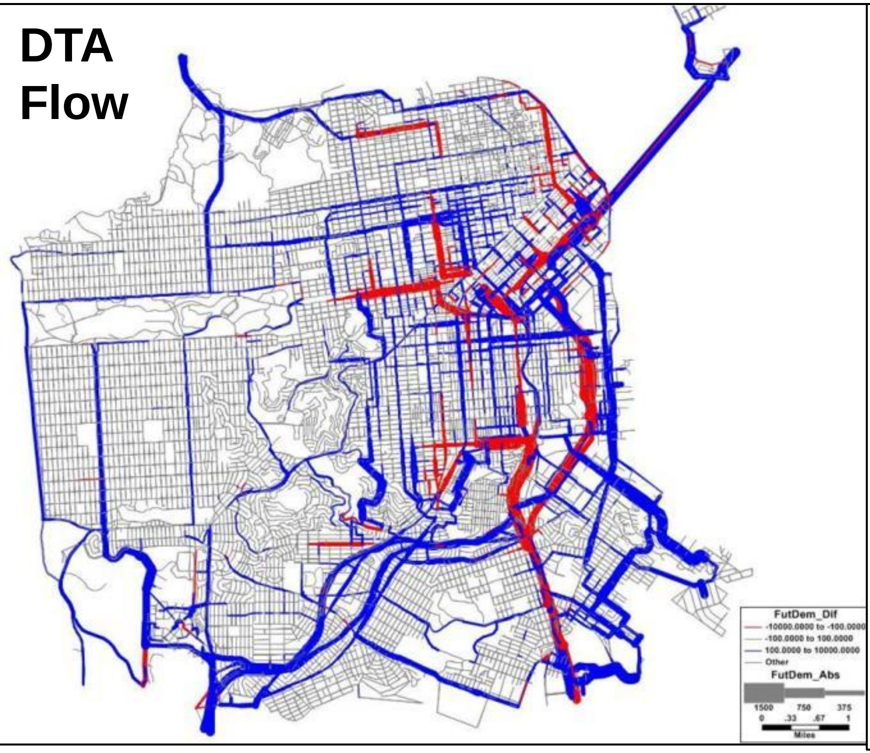


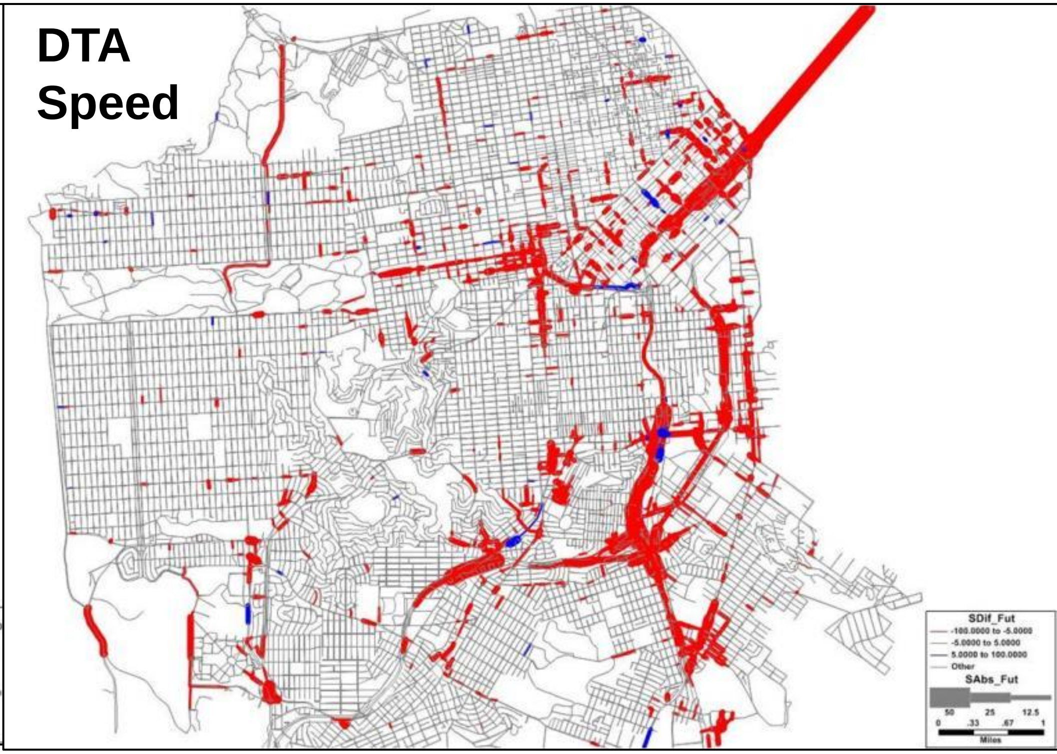
Map of Speed Change for Network Change test (Red links – speed decrease of at least 5 mph, Blue links – speed increase of at least 5 mph)

Future Demand Test



- Used 2040 demand levels from SF-CHAMP with 2012 base network
- Car trips increased by 21% and truck trips stayed about the same



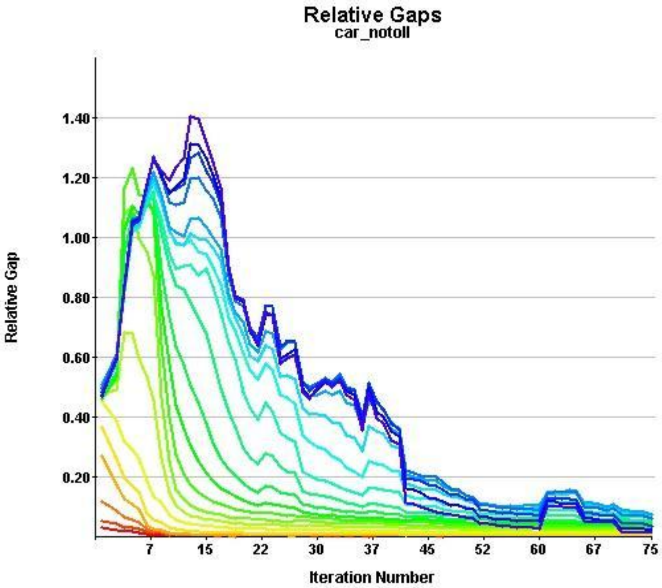


Map of Flow Change for 2040 Demand test from 5:00 to 6:00 pm (Red links – flow loss of at least 100 vehicles, Blue links – flow gain of at least 100 vehicles)

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

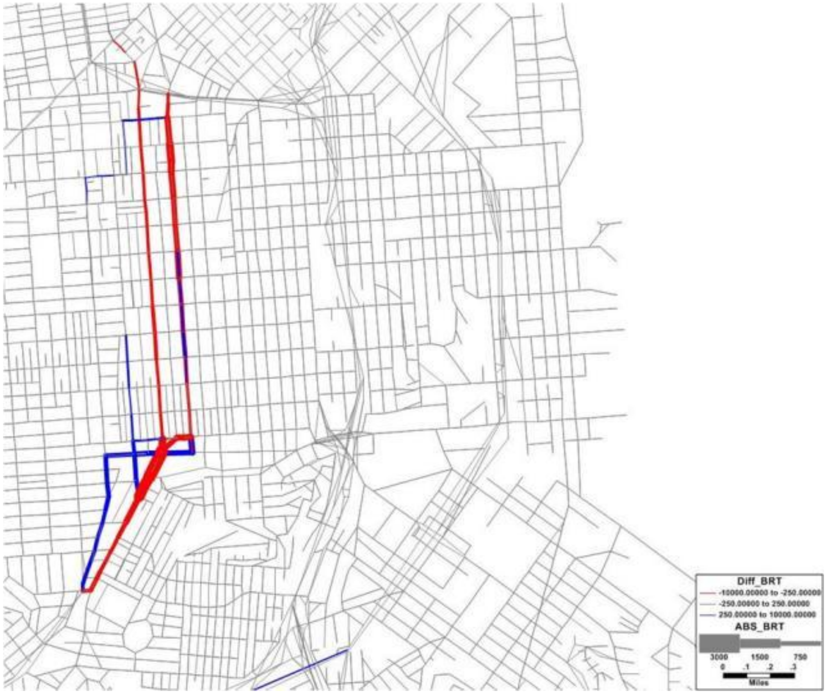
- Added a center-running BRT lane on Mission St in both directions from 14th St to Cesar Chavez St
- Mission went from 2 lanes in each direction to 1 NB auto lane and no SB auto lanes
- South Van Ness went from 2 lanes in each direction to one NB lane and three SB lanes



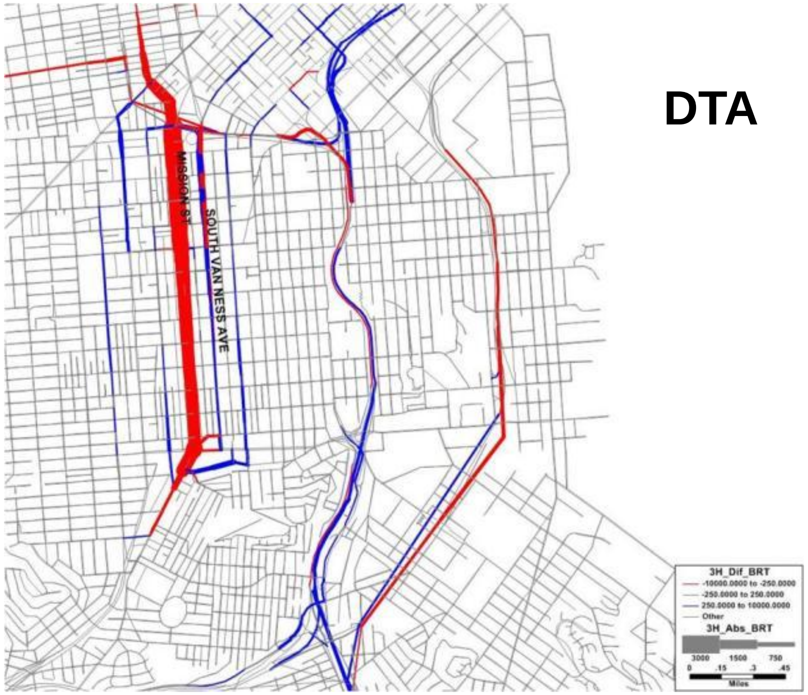
BRT Application Test – Static vs. DTA Flow Maps

- 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

Static



DTA



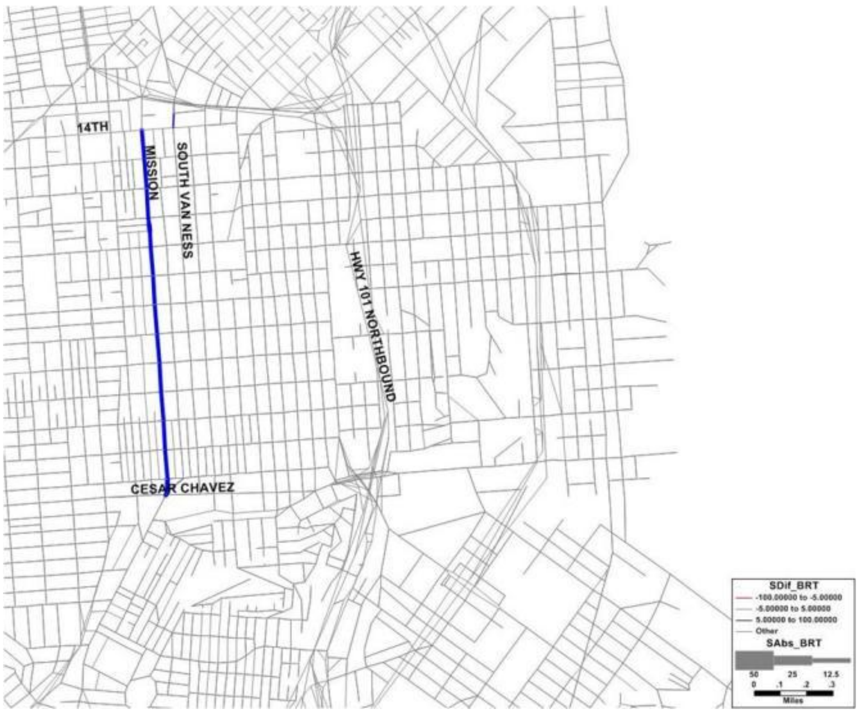
Map of Flow Change from Static BRT Test (Red links – flow loss of at least 250 vehicles, Blue links – flow gain of at least 250 vehicles)

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

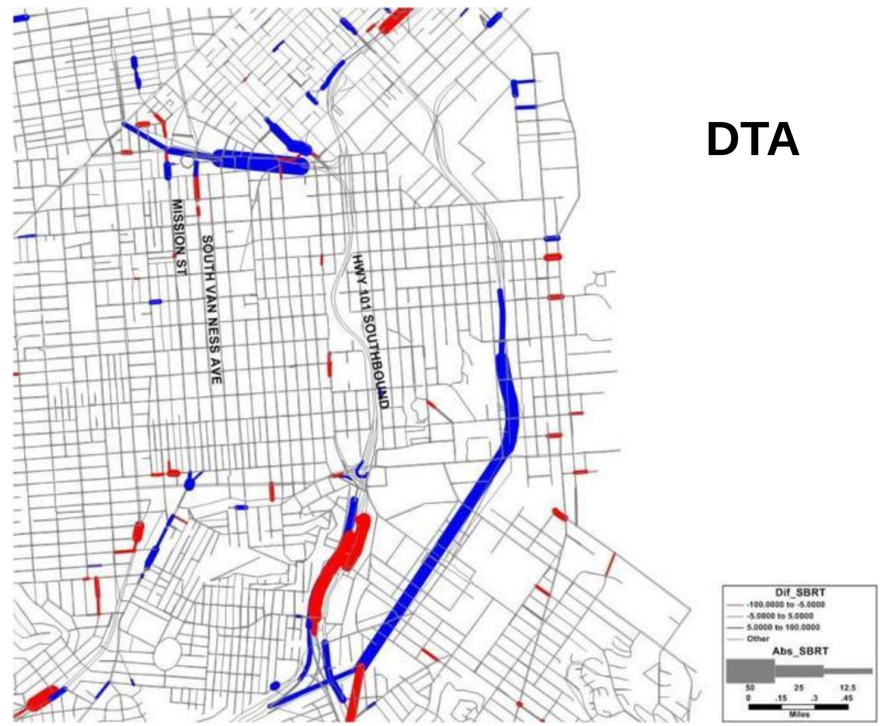
- **DTA Model shows greater impacts on speed**
- **Static model shows little change in speed even on links that showed larger changes in flow.**

Static



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)

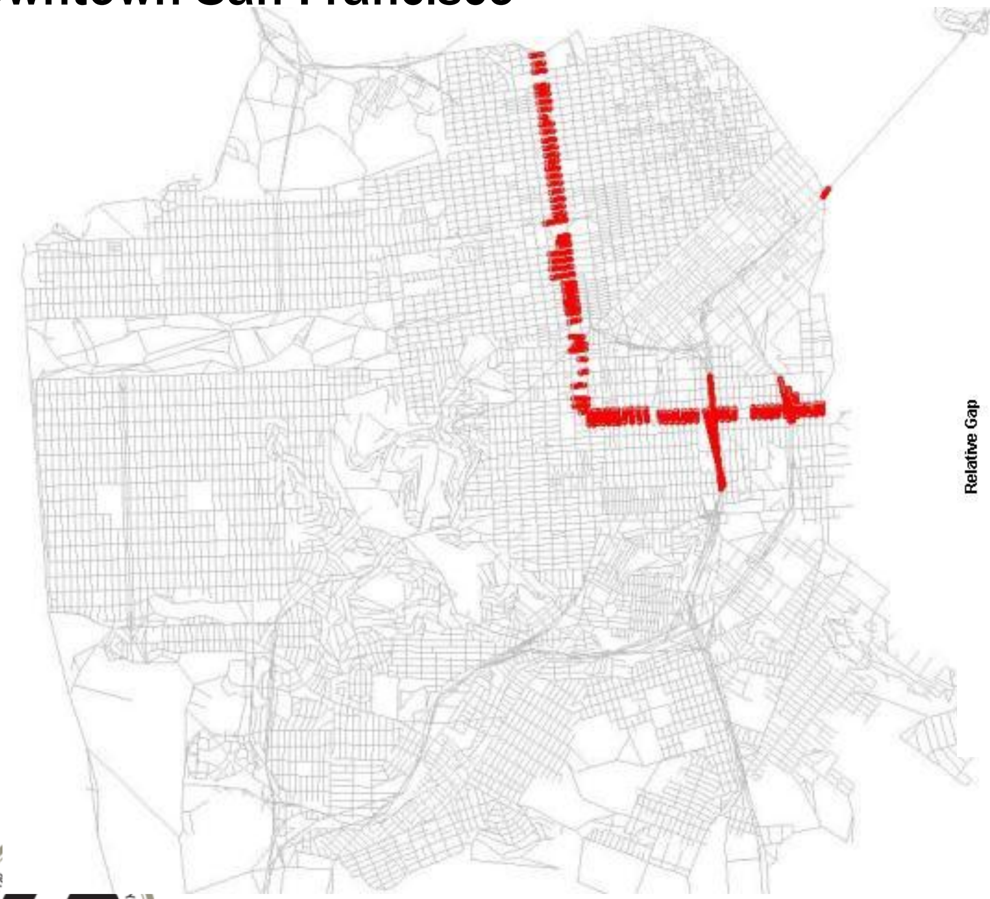
DTA

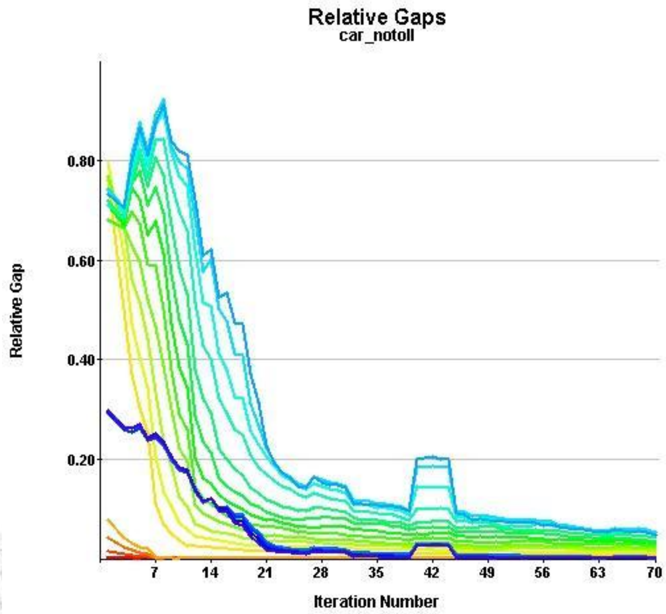


Map of Speed Change from DTA BRT Test (Red links – speed loss of at least 5 mph, Blue links – speed increase of at least 5 mph)

Congestion Pricing Application Test

- **Added a $3 fee to anyone crossing the cordon to manage congestion in downtown San Francisco**

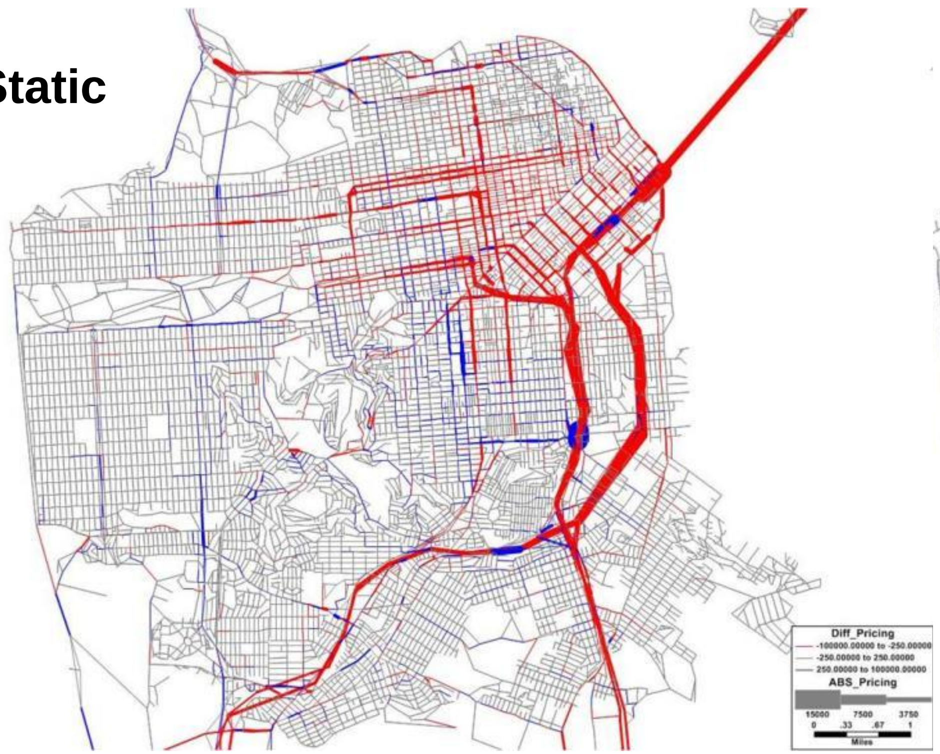




Congestion Pricing Application Test – Static vs. DTA Flow Maps

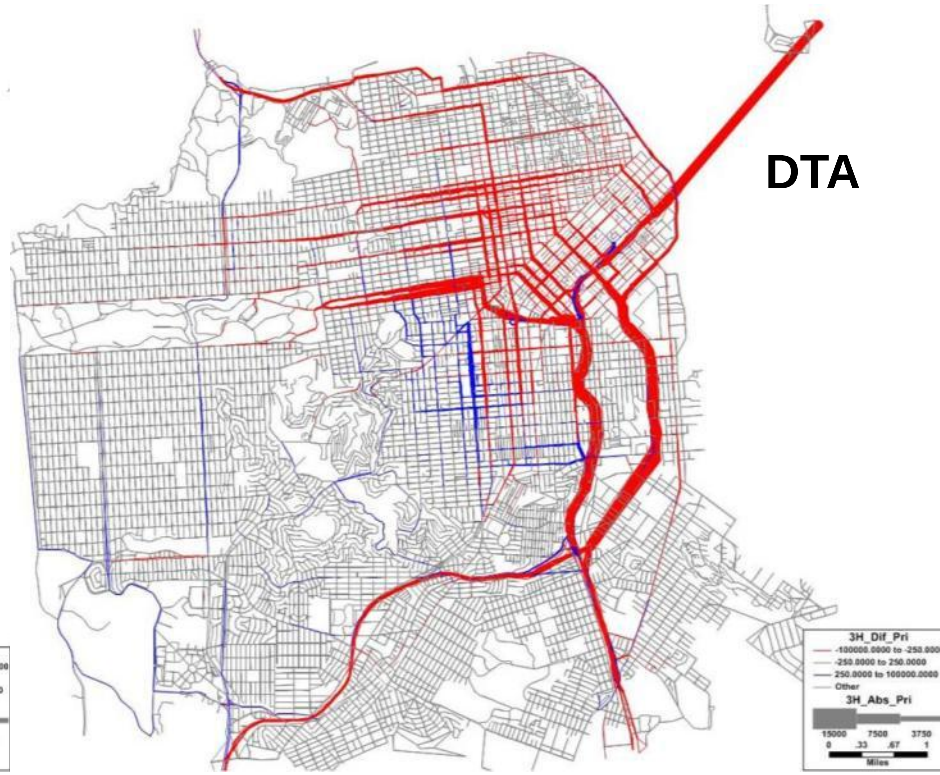
- DTA Model shows a much clearer diversion to paths outside the cordon
- Static model shows some odd shifts that in the Northern region including increases in EB traffic going toward the CBD

Static



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)

DTA

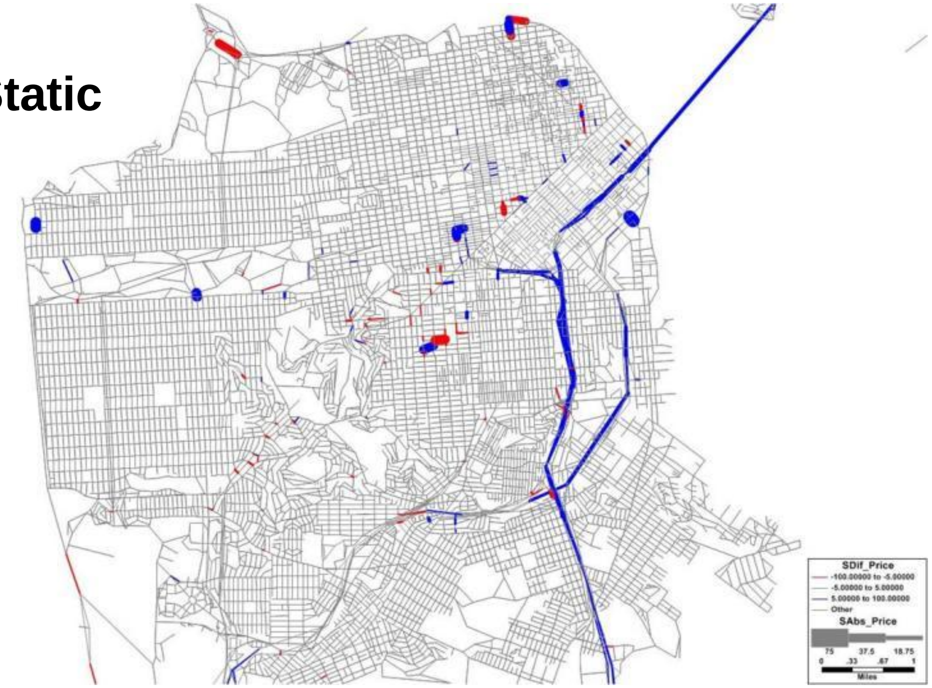


Map of Flow Change from DTA Pricing Test (Red links – flow loss of at least 250 vehicles, Blue links – flow gain of at least 250 vehicles)

Congestion Pricing Application Test – Static vs. DTA Speed Maps

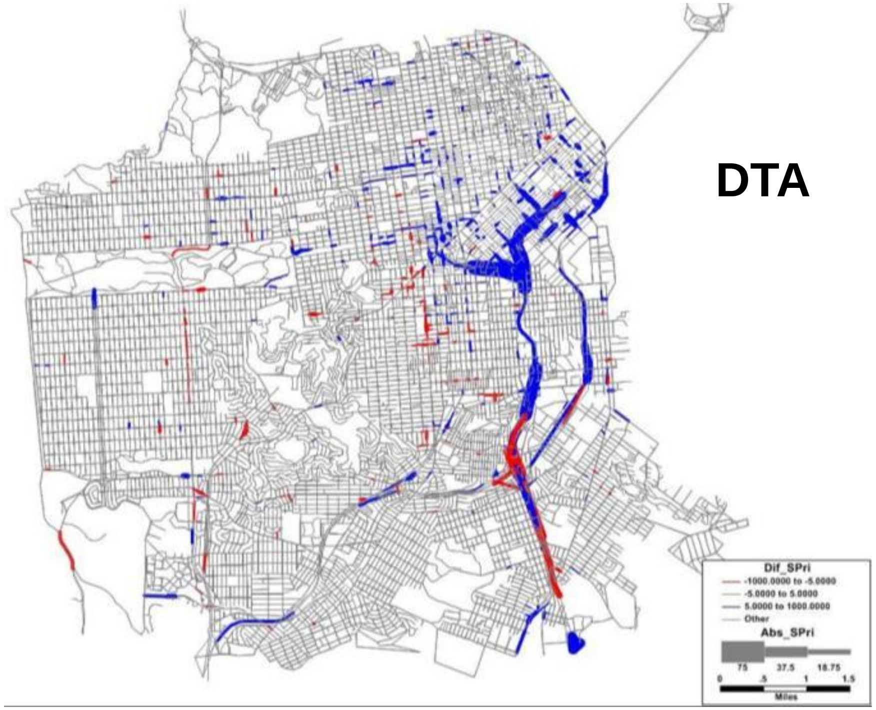
- **DTA Model shows more widespread impacts on speed with faster speeds in most of the CBD.**
- **Using the static model results could greatly underestimate the potential travel time impacts in the CBD.**

Static



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)

DTA



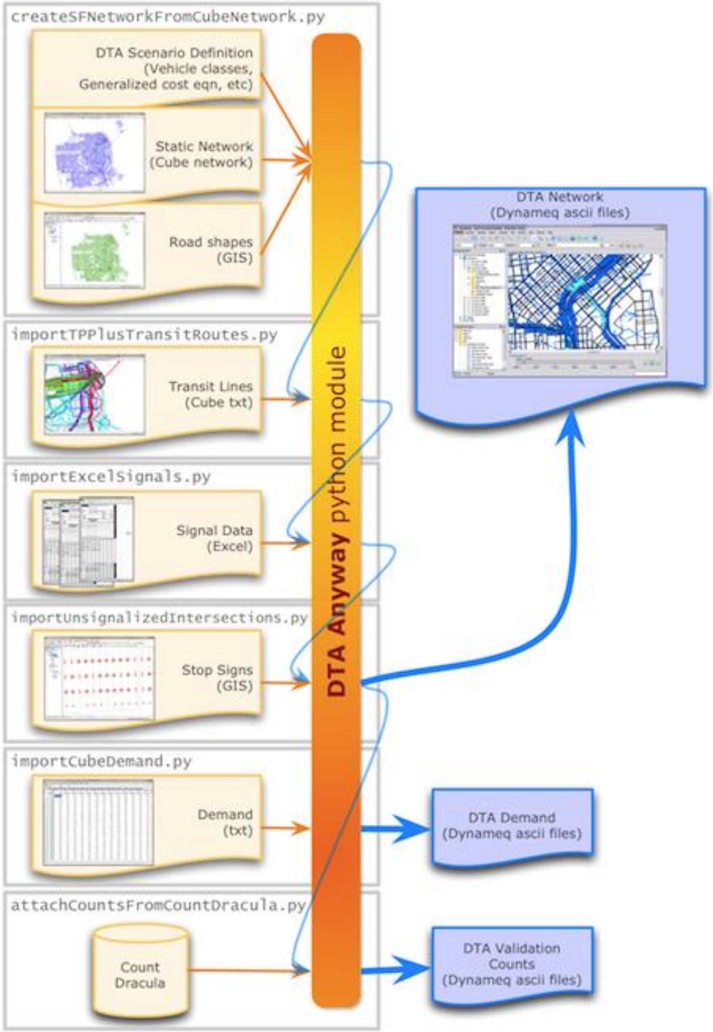
Map of Speed Change from DTA Pricing Test (Red links – speed loss of at least 5 mph, Blue links – speed increase of at least 5 mph)

CONCLUSIONS & LESSONS LEARNED

Gregory Erhardt – erhardt [at] pbworld [dot] com

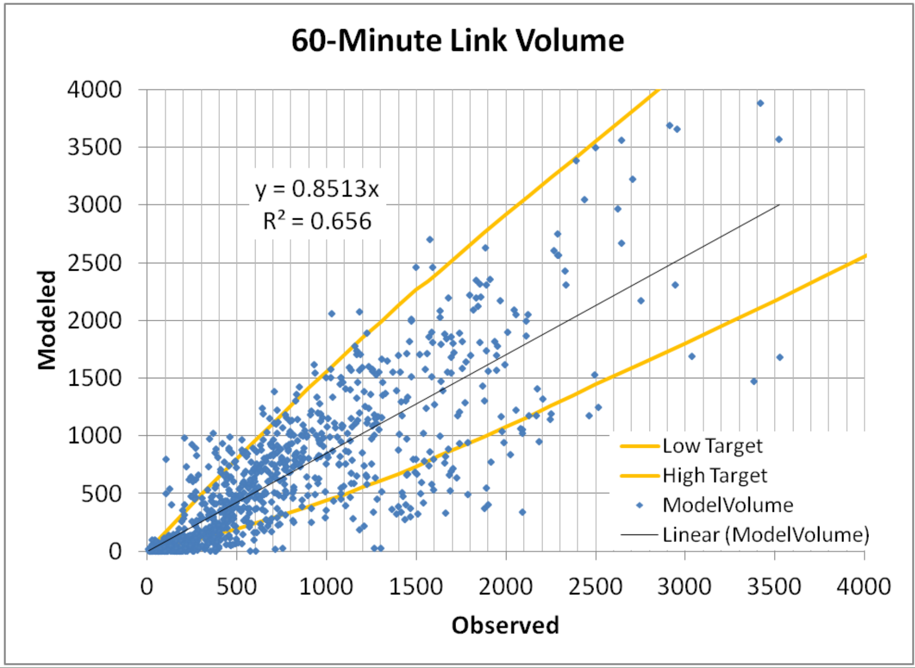
Software and Application Process

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



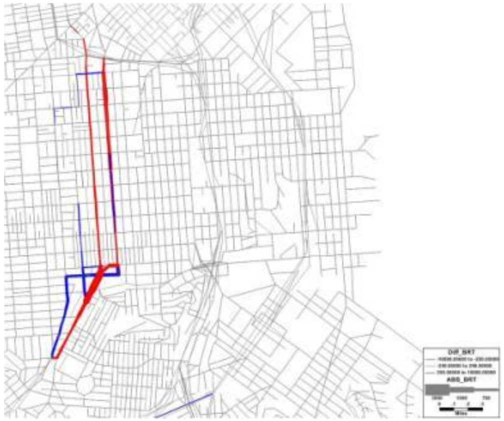
Calibration and Validation process

- 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.

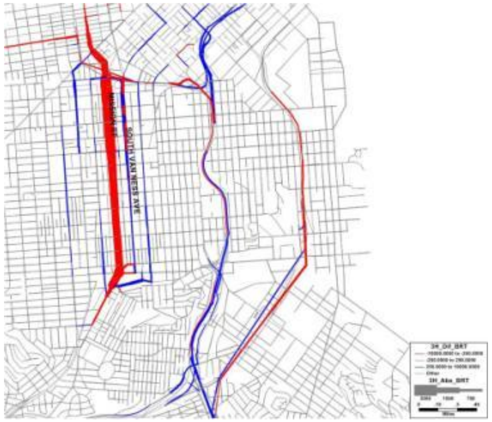


Sensitivity Testing and Related

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

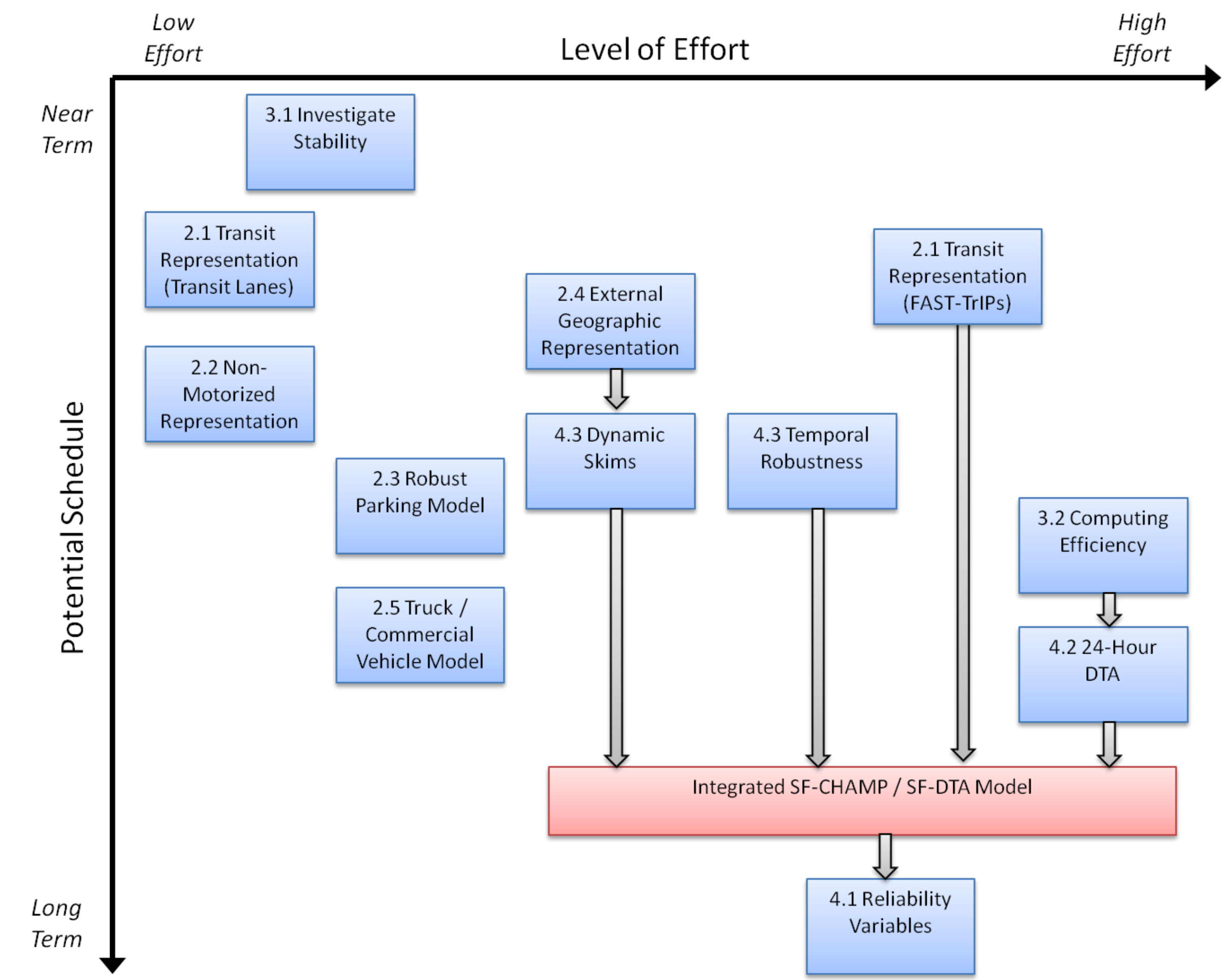


Map of Flow Change from Static BRT Test (Red links – flow loss of at least 250 vehicles, Blue links – flow gain of at least 250 vehicles)



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



Future Work - Deployment

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

Questions?

www.sfcta.org/dta

dta.codegoogle.com