I-210 Connected Corridors Pilot

Analysis, Modeling and Simulation Review

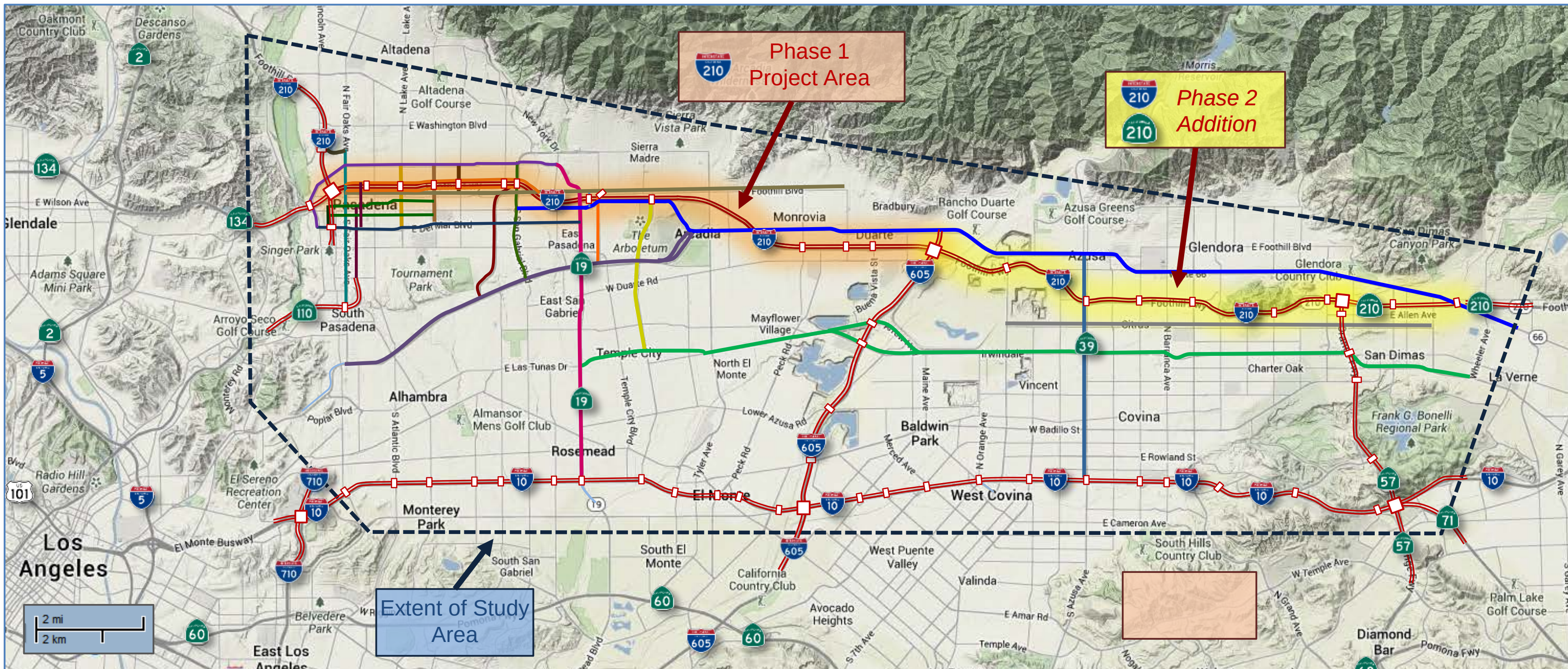
10/25/2016

Outline

- **Overview of I-210 Pilot ICM Project**
- **Response Planning Needs**
- **Modeling Approach**
- **Modeled Elements**
  - Roadway elements
  - Traffic signals
  - Transit services
- **Calibration Approach**
- **Building the Traffic Demand**
  - Traffic State Estimation for Prediction
  - Ensuring Input Data Quality
  - Demand Modeling
  - Route Choice Modeling
- **Modeling Response Plans**
  - Response Planning Modeling
- **Using the Model**
  - Model Execution
  - Corridor Evaluation
- **Research and Partnering**

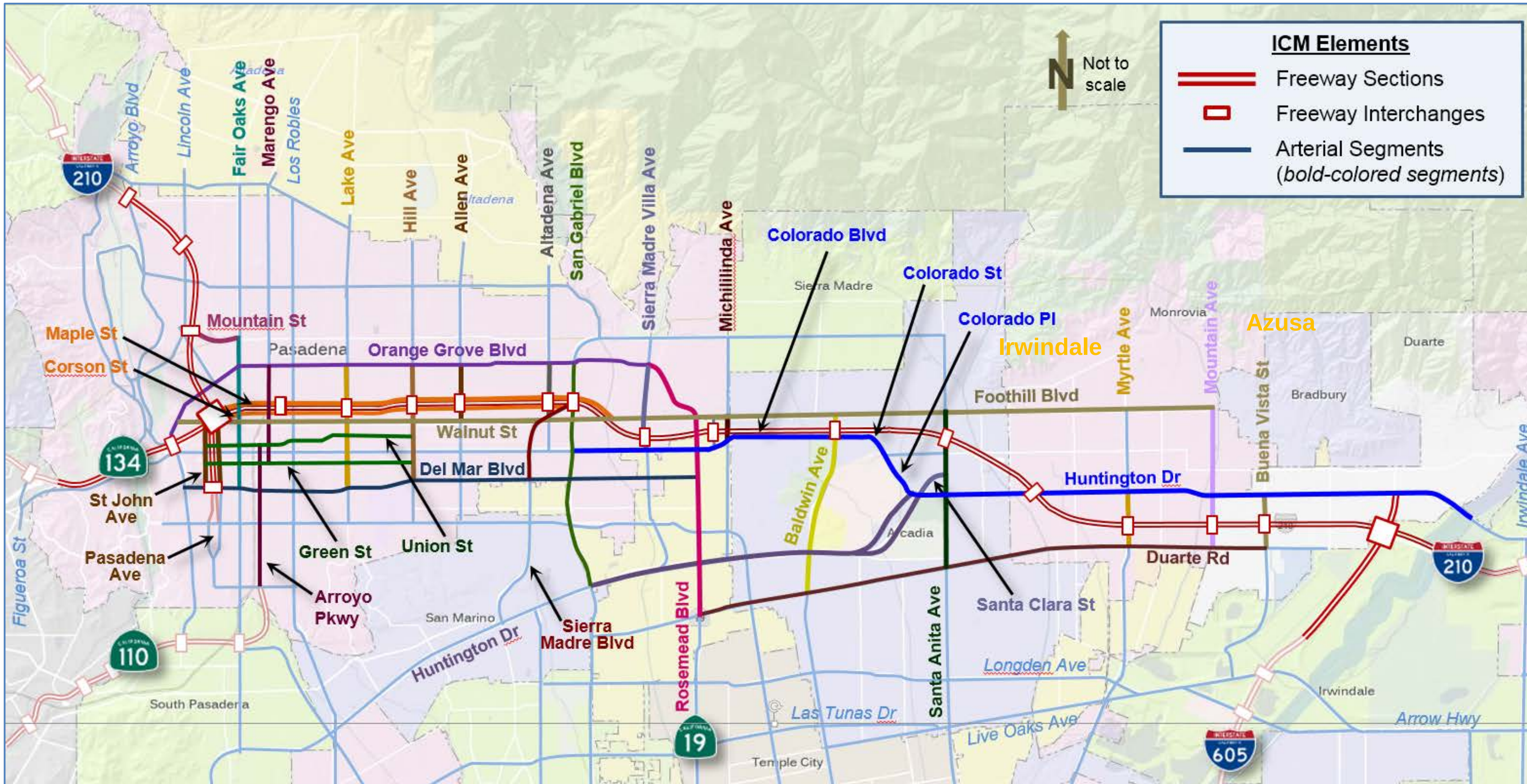
I-210 Pilot ICM Project

I-210 Corridor Area



Metro

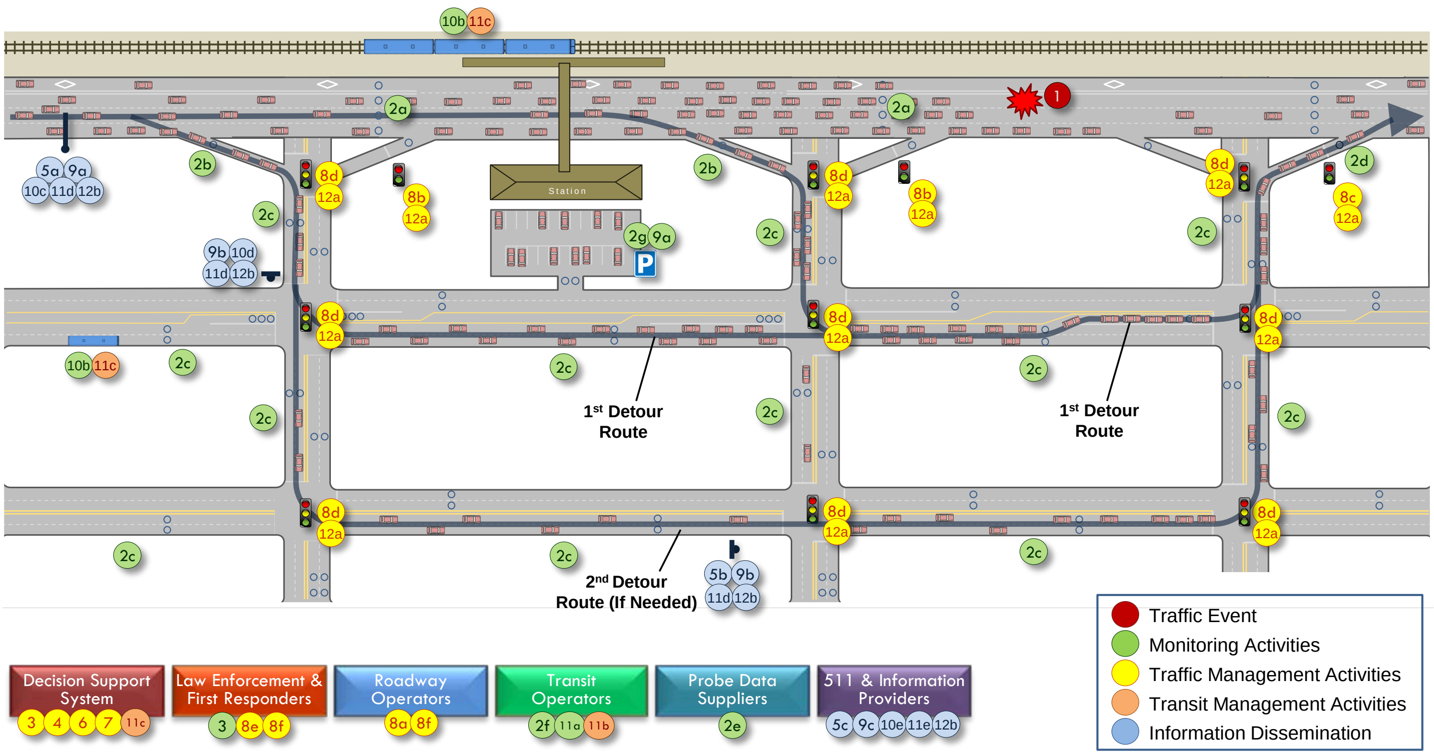
I-210 Pilot ICM: Managed Roadways



Pasadena | Unincorporated County Area | Arcadia | Monrovia | Duarte

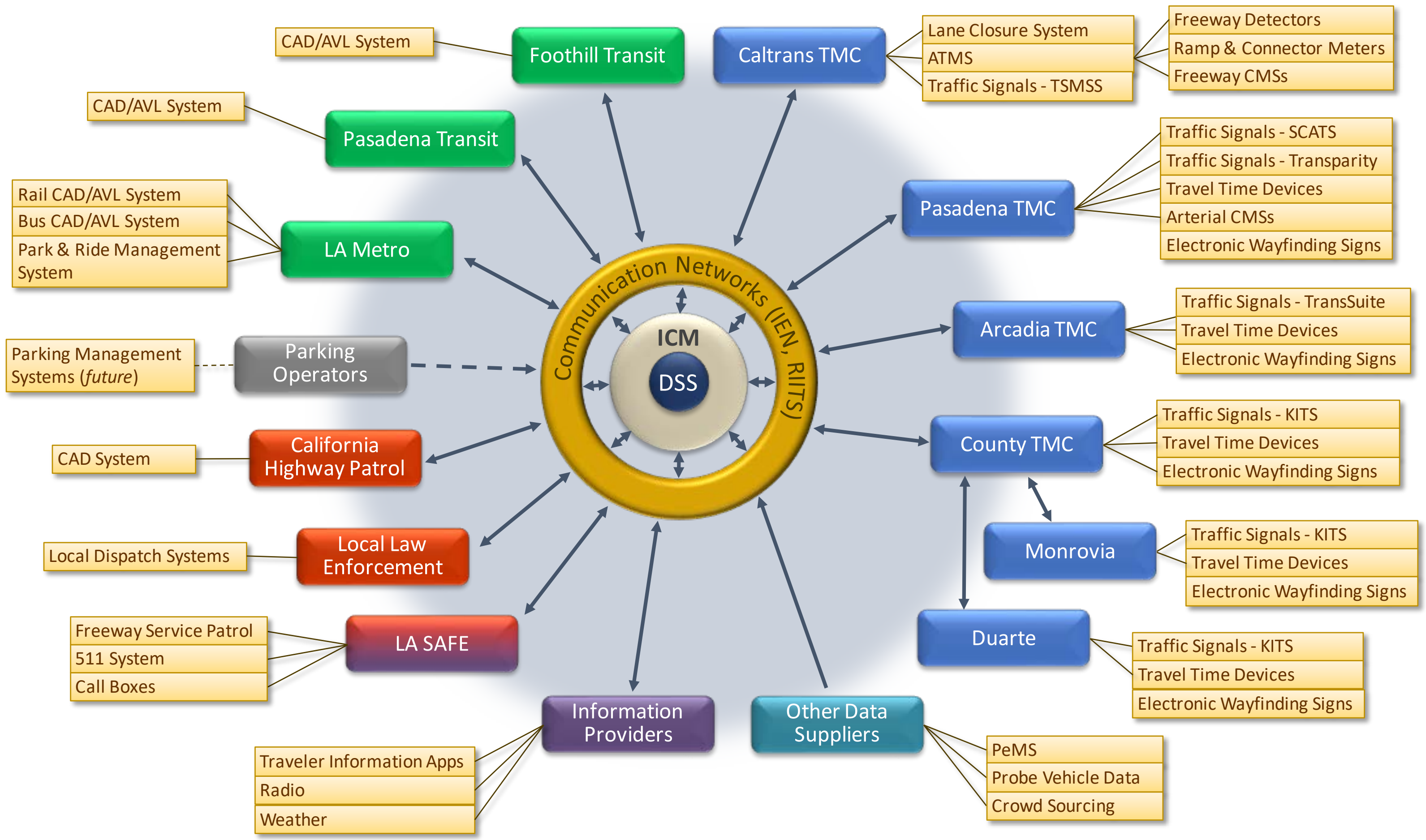
Caltrans · Metro · Foothill Transit · PATH

I-210 Pilot ICM: Responding to Incidents

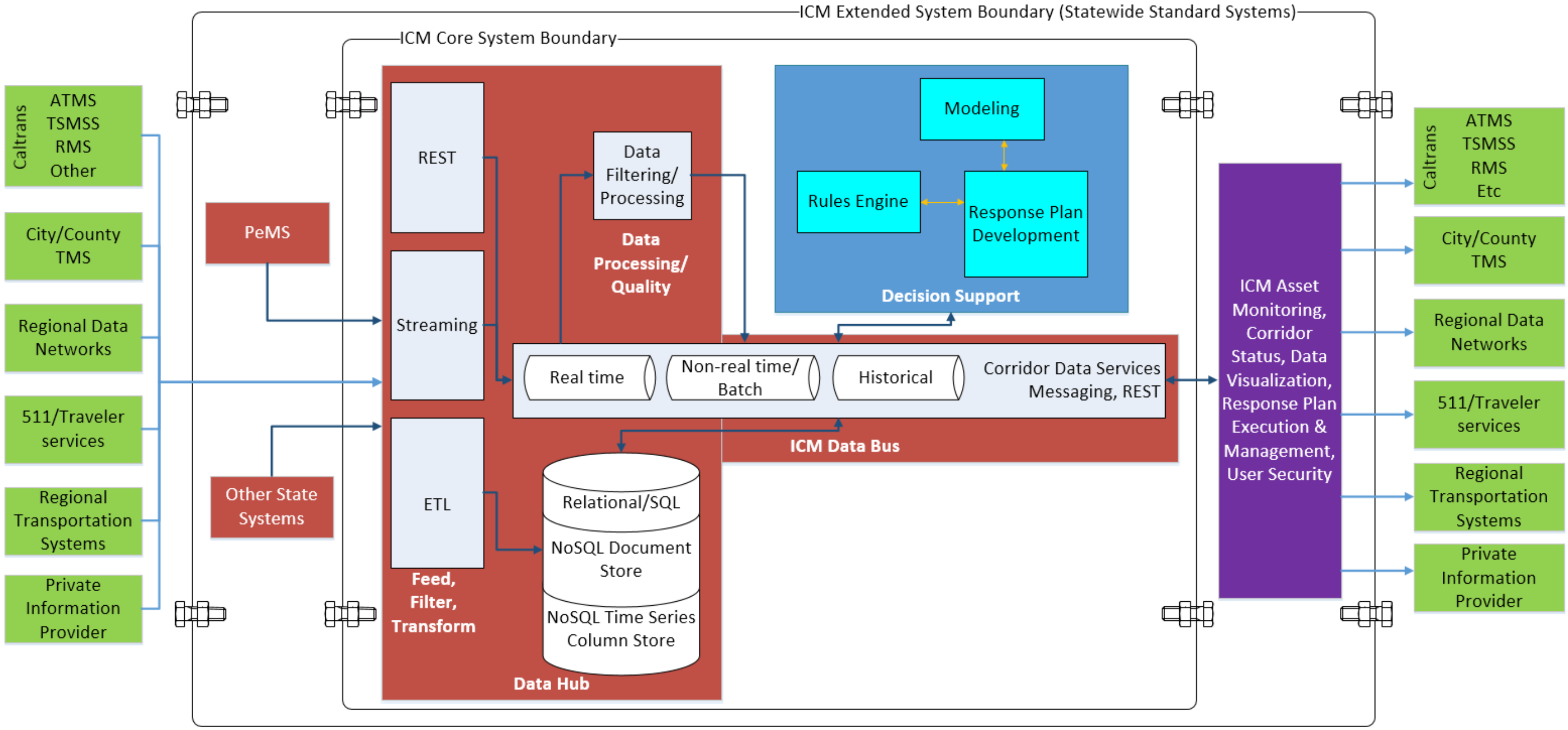


1 – Freeway Accident
2 – Detection of Changing Traffic Conditions
3 – Incident Identification
4 – Incident Characterization
5 – Incident Information Dissemination
6 – Initial Impact Assessment
7 – Response Planning
8 – Implementation of Traffic Plan
9 – Route Information Dissemination
10 – Dissemination of Information about Transit Options
11 – Transit Service Adjustments

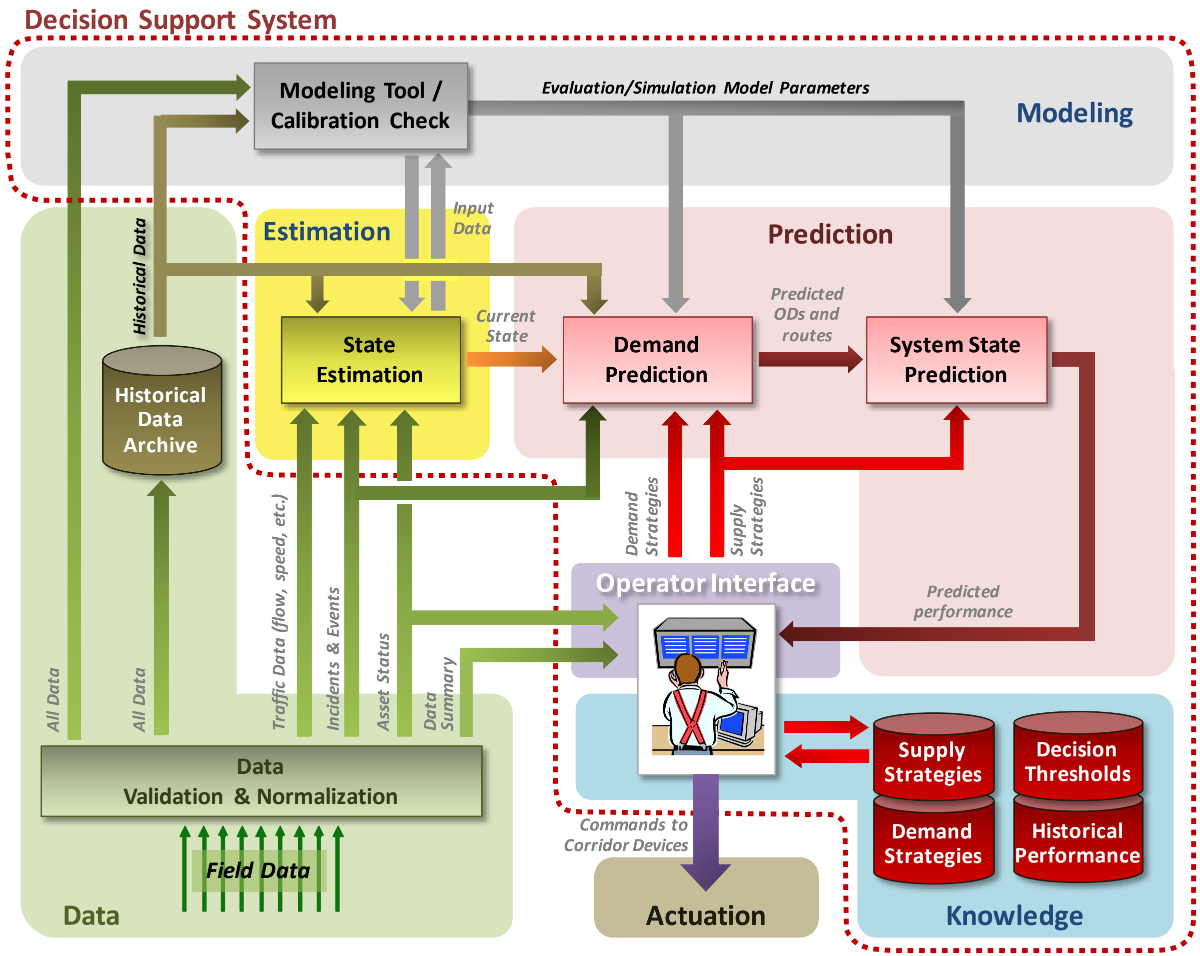
I-210 Pilot ICM: Connected Systems



Proposed ICM Architecture



I-210 Pilot ICM: Decision Support System



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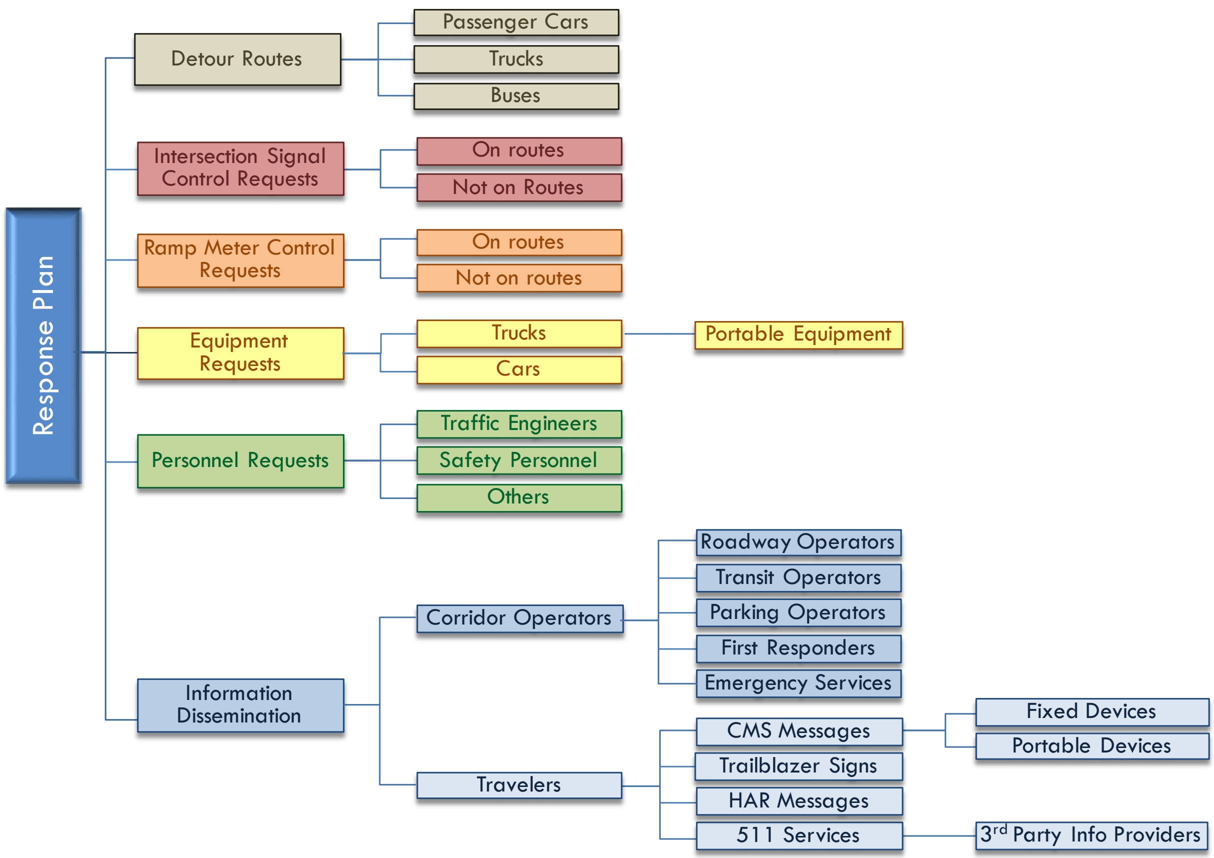
Response Planning Needs

Response Plan Elements

- Action items associated with a response plan



Preliminary Alternate Route "Menu"

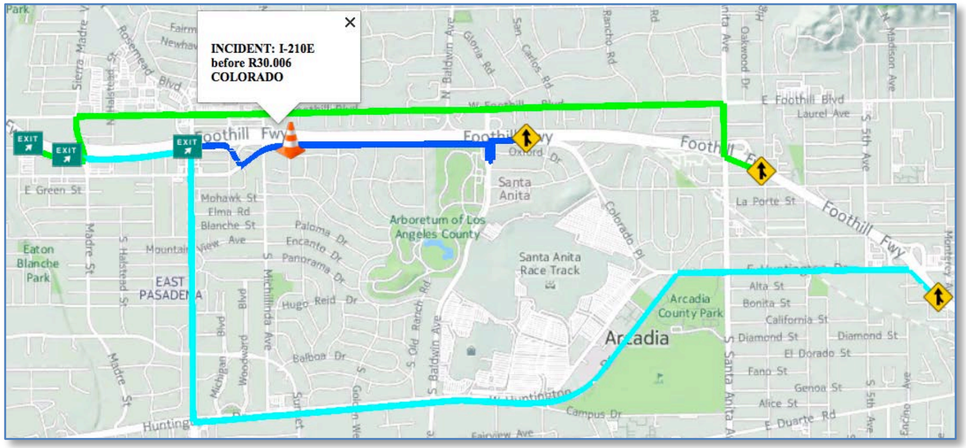
- ~300 *possible* alternate arterial routes **have been identified between Lake and Buena Vista interchanges within I-210 corridor**

- **This set of 300 alternate routes is our "menu" of choices.**

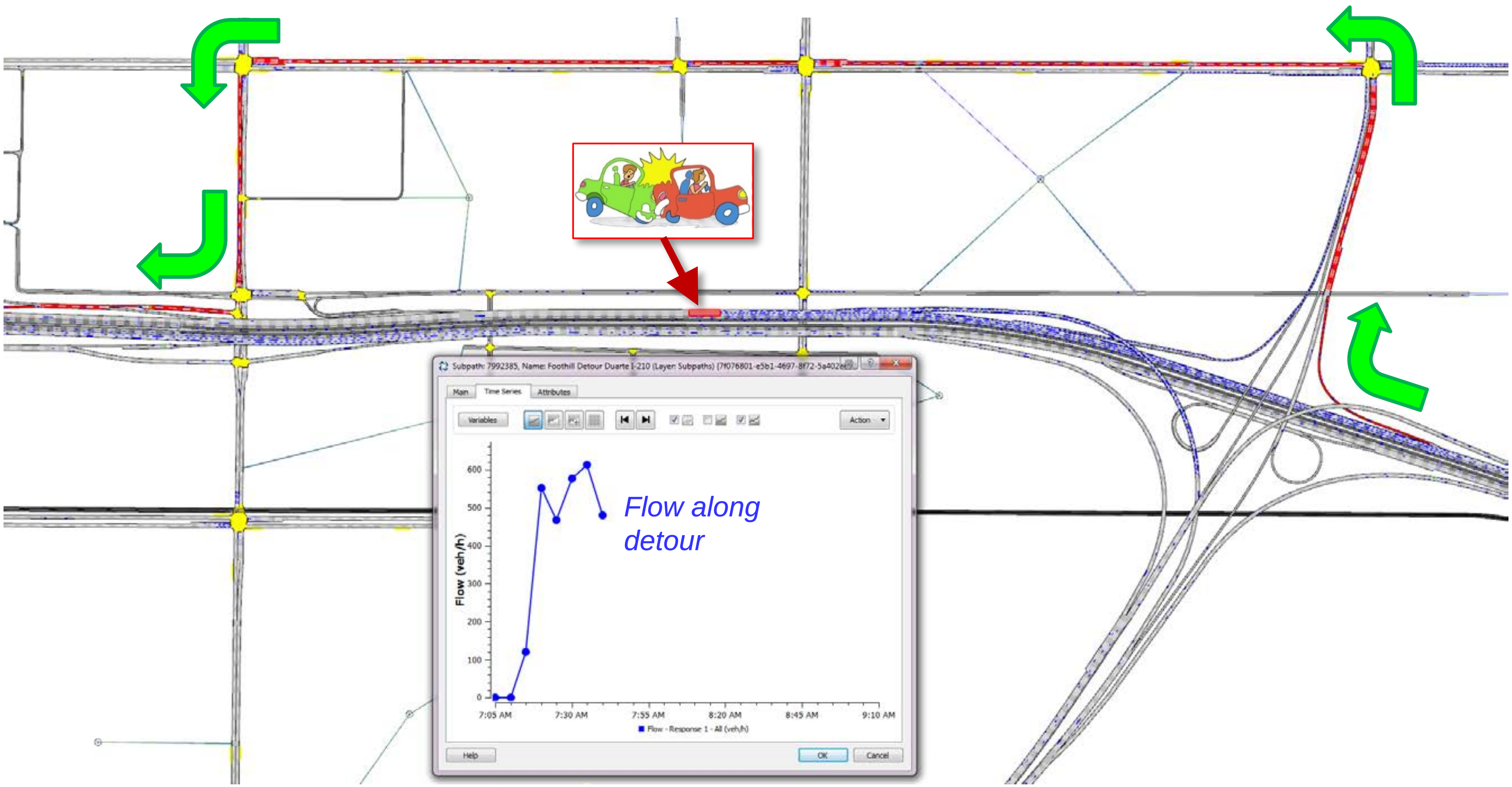
Selection of Alternate Routes for Specific Incidents

- **Response to a given incident may include 1 to 3 alternate routes from the "menu" of ~300 preliminary routes**
- **Factors affecting choice**
  - Location of incident
  - Prevailing traffic conditions on freeway and arterials
  - Ability of route to provide effective relief

Need to evaluate the impact of each response plan on corridor



Evaluating Potential Response Plans



Performance Metrics Produced by Aimsun

Measures Calculated by Aimsun	Value	Standard Deviation	Units
Network flow (throughput)	36,098.94	153.79	veh/h
Total Travelled Distance (VMT)	355,245.74	2,262.65	mi
Total Travel Time (VHT)	8,436.16	234.80	h
Travel time per mile	104.02	3.00	sec/mi
Delay per mile	41.03	3.00	sec/mi
Stop time per mile	22.12	2.13	sec/mi
Traffic density	14.51	0.42	veh/mi
Average network speed	41.25	0.73	mph
Total number of stops	36,663.48	1,607.83	#
Total number of lane changes	466,864.56	2,285.11	#
Number of lane changes per mile	1,599.70	7.83	#/mi
Fuel consumption	15,497.75	157.91	gal
Mean vehicle queue	480.65	34.46	veh

All metrics calculated for: - Each vehicle type
- All vehicles

Metrics also available for: - Specific subpaths

Target Performance Metrics

- **Vehicle-based metrics**
  - Vehicle-miles traveled (VMT)
  - Vehicle-hours of travel (VHT)
  - Vehicle delays
- **Person-based metrics**
  - Person miles traveled (PMT)
  - Person hours traveled (PHT)
  - Delay
- **Travel times**
  - Average travel times /speeds
  - Travel time reliability
- **Environmental metrics**
  - Fuel consumption
  - Vehicle emissions

Requires assumption on average number of person per vehicle

Underlying Data Quality Needs

- **Importance of high-quality data—including its timeliness, accuracy, and coverage—cannot be overstated**

- **Data quality affects**
  - Estimation of origin-destination trip patterns
  - Network modeling and calibration
  - Evaluation of response plans
  - etc.

- **Quality of work depends directly on quality of data**
  - Missing data → reduced situational awareness
    - Unable to locate routes with available capacity
  - Bad data → bad decisions
    - → Bad management and worse traffic
    - → Increased risk to pilot deployment

Project Status

AMS Accomplishments

- **Model development**
  - Completion of Synchro AM and PM models for control plan optimization
  - Completion of I-210 Corridor Model Elements
    - ~1000 lane miles of road
    - ~5000 traffic detectors
    - 459 signalized intersections and control plans -- weekday/weekend
    - 45 freeway ramp meters -- TOD and LMR control plus queue / mainline override
    - Transit: Metro gold line and all bus routes
  - Preliminary calibration of eastern subnetwork using 2008 SCAG data

AMS Accomplishments

- **Corridor analyses**
  - Data/instrumentation gaps
  - Operational needs
  - Funding applications
- **Response planning**
  - Preliminary "menu" of alternate routes for response planning
- **Estimation**
  - Now running freeway estimation
  - Feasible approach for arterial being tested
- **Data quality**
  - Substantial data quality improvements in cooperation with stakeholders
- **Running the model**
  - Aimsun running on the Amazon cloud

AMS Schedule Moving Forward

Date	Milestones				
	2016	2017			
	Q4	Q1	Q2	Q3	Q4
SCAG teamwork and OD data					
Obtain 2012 ODs over tier 3 TAZs					
New ODs imported to Aimsun					
Data quality and vetting data sources					
PeMS DQ report (weekly)					
Arterial DQ report (bi-weekly)					
Comparison of arterial mid-block, turning studies, and loop data					
Implemented method for loop data filtering / processing					
Arcadia loop data imported to Aimsun					
Pasadena loop data imported to Aimsun					
Calibration					
Calibration of eastern network portion using 2008 SCAG data					
Calibration of corridor freeway network using 2012 SCAG data					
Calibration of corridor freeway and arterial network					
Refinement of calibrated corridor network					
Build and evaluate response plans					
Reroute feasibility study					
Eastbound reroutes evaluation					
Westbound reroutes evaluation					
Reroutes evaluation refinement					
Management					
AMS Presentation					
FHWA AMS Workshop					

Modeling Approach

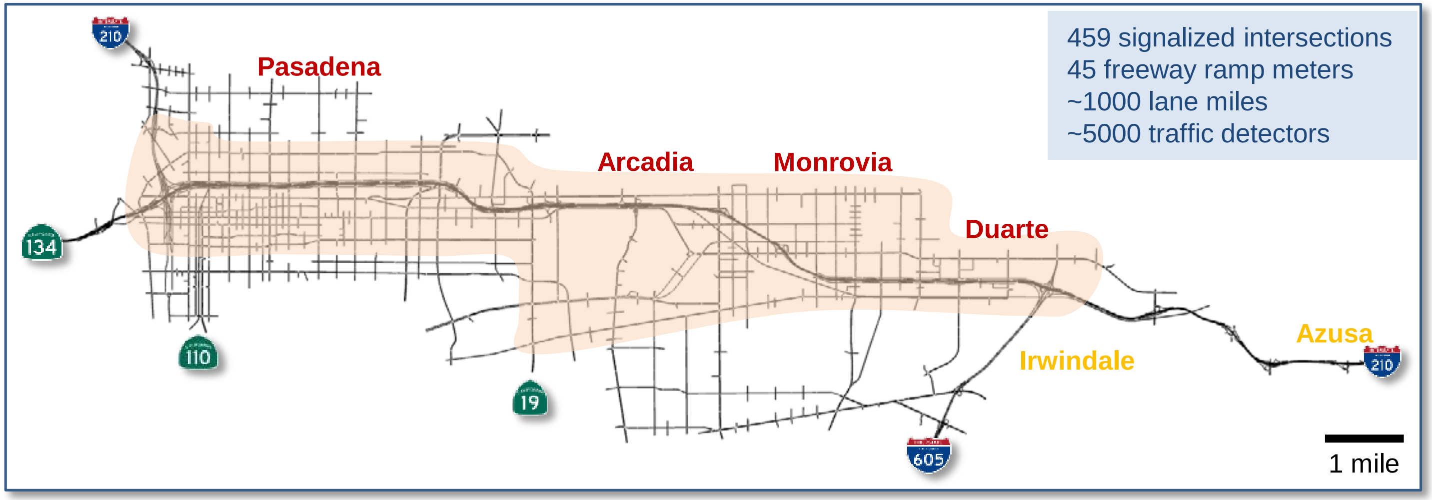
Purpose of Model

- **Understand how to manage incidents on the I-210 corridor**

- **Take account of short-term traveler responses such as en route diversion triggered by**
  - Unusual congestion
  - Information dissemination
- **Guide the assembly and selection of appropriate response plans for potential deployment**
- **Performance evaluation**

Geographic Scope

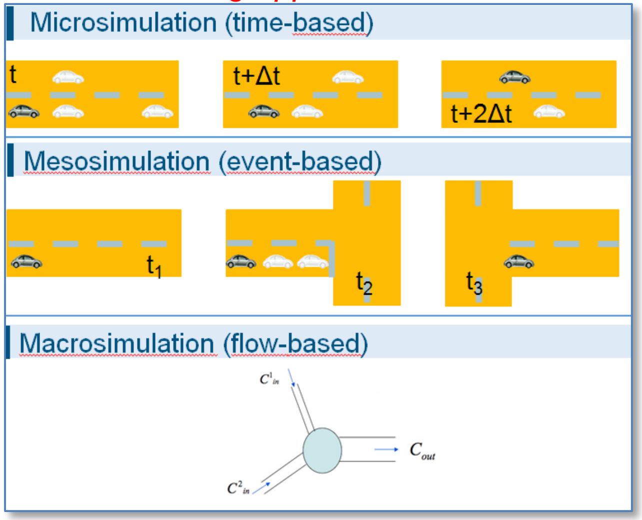
- **Primary scope**
  - Modeling of freeways and main arterials in Pasadena, Arcadia, Monrovia, and Duarte
- **Modeling extensions**
  - Modeling of freeway to Azusa to adequately capture bottlenecks
  - Modeling of key arterials outside main area of interest to capture routing behavior that may effect corridor operations



Simulation Approaches

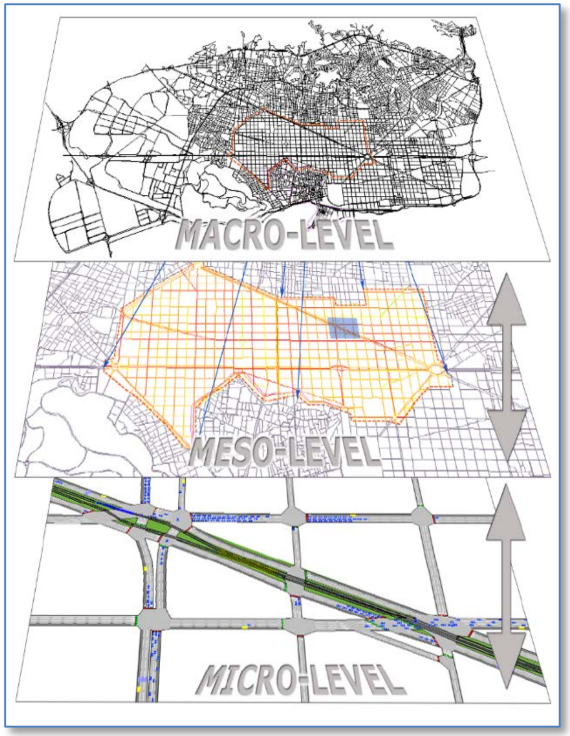
- **Possible modeling approaches**
  - Microscopic
    - Modeling of individual vehicles
    - Complex car-following and lane-changing models
  - Mesoscopic (micro-based)
    - Modeling of individual vehicles or groups of vehicles
    - Simplified car-following model
    - May or may not include lane modeling
  - Mesoscopic (macro-based)
    - Behavior based on deterministic relationship between flow, speed, and density
    - More detailed link-node representation than macro models (example: CTM model)
  - Macroscopic
    - Behavior based on deterministic relationship between flow, speed, and density
    - Simple link-node network representation

Aimsun Modeling Approaches



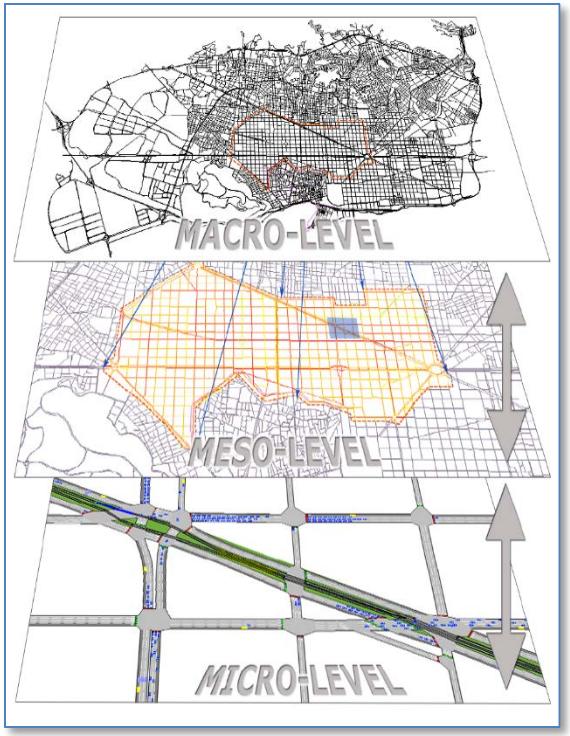
Which Modeling Approach to Use?

- **Consideration #1 – Simulation time**
  - Computational load increases with number of vehicles and network size, particularly with microscopic models
  - Advantage to macroscopic models
- **Consideration #2 – Replication of vehicle-based applications**
  - Microscopic approach allows a more accurate replication of applications based on individual vehicles
    - Vehicle-actuated traffic signal control
    - Vehicle-vehicle (V2V) and vehicle-infrastructure (V2I and I2V) applications



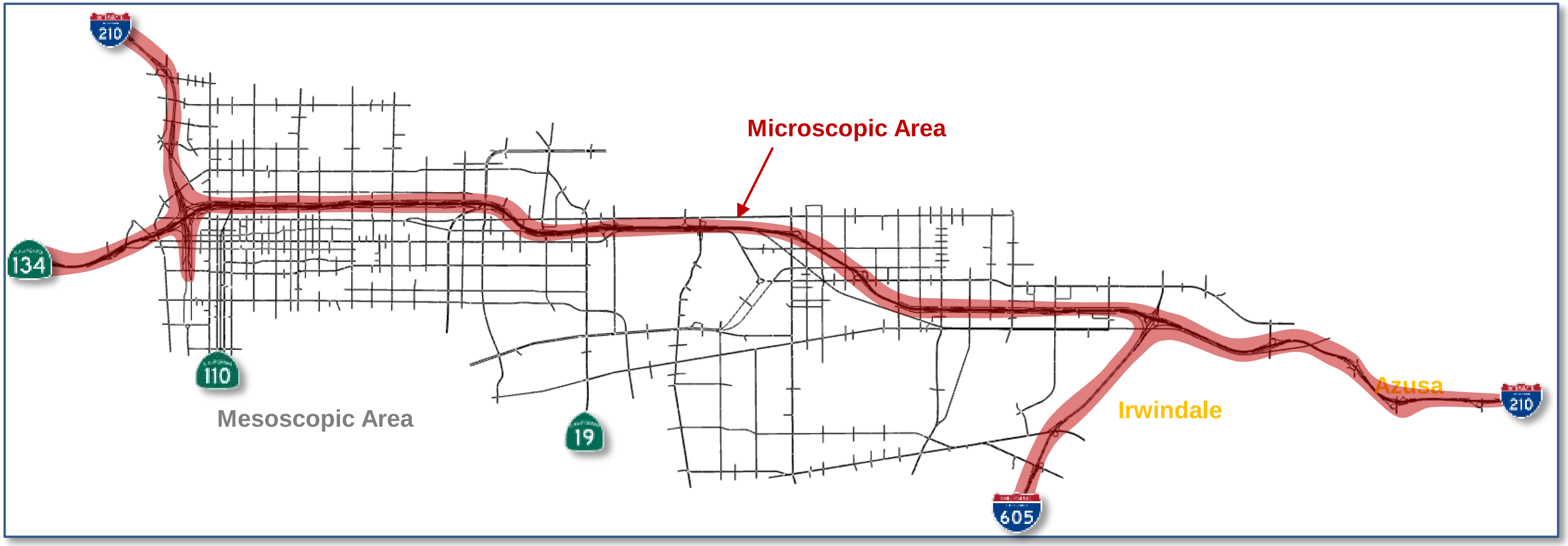
Which Modeling Approach to Use?

- **Consideration #3 – Calibration difficulty**
  - Calibration of large network a challenge regardless of the approach used
  - Macroscopic approach generally simplest to calibrate
- **Consideration #4 – Ability to simulate new situations (prediction)**
  - O-D based models better suited for evaluating:
    - New situations for which no data exists
    - Impacts of routing



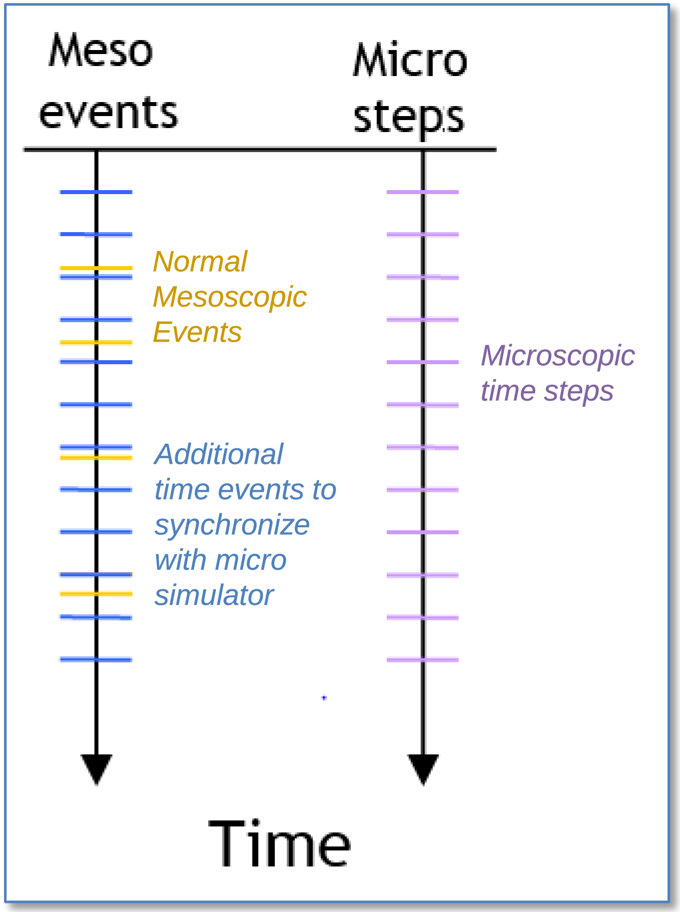
Selected Modeling Approach

- **Hybrid simulation in Aimsun**
  - Microscopic simulation for mainline freeway and freeway ramps and some arterials
  - Mesoscopic simulation for remainder of network



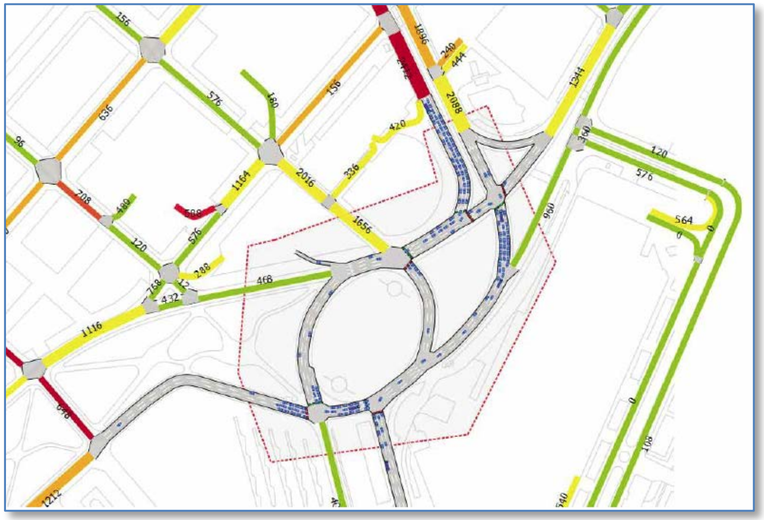
Impacts on Modeling

- **Different time processes in micro and meso model areas**
  - Microscopic area: Time-based simulation
    - Simulation proceeds at fixed intervals
  - Mesoscopic area: Event-based simulation
    - Vehicle generation
    - Vehicle entrance in network
    - Vehicle node movement
    - Change in traffic signal state
    - Calculation of statistics
    - Change in traffic demand matrix



Impacts on Modeling

- **Different vehicle behavior models**
  - Microscopic model
    - Car-following and lane-changing model applied every time step
  - Mesoscopic model
    - Vehicle only considered when entering and exiting a link → Movement within link not simulated
    - Calculates expected link exit time
    - Determines lane on which a vehicle would be at the end of a link



- **Need to pay attention to traffic behavior at micro/meso boundary**
  - Area where many previous models have failed

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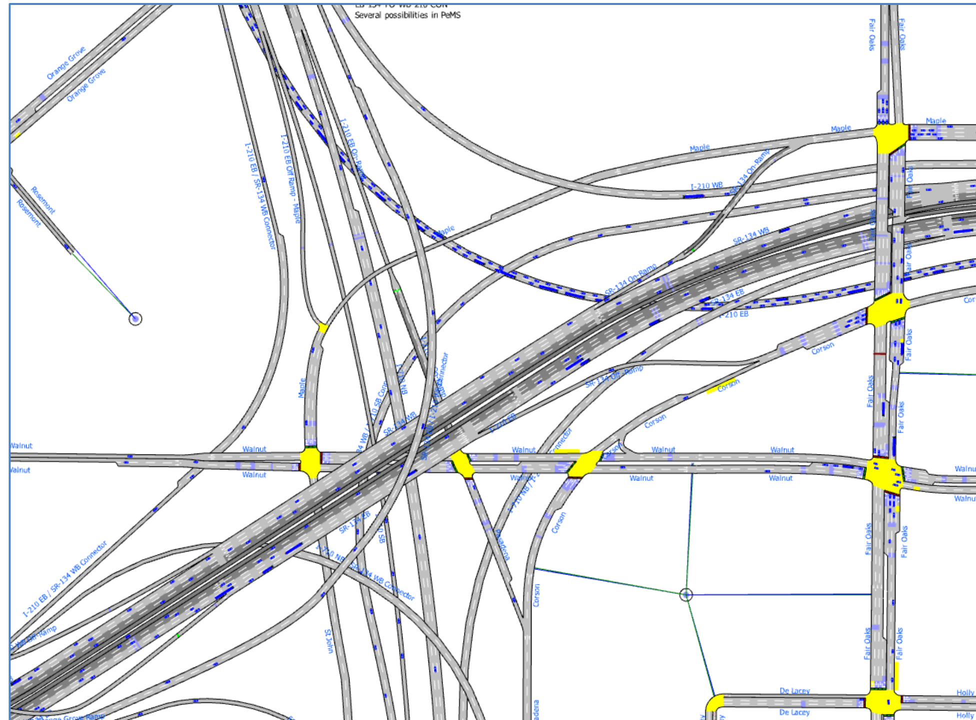
Roadway Elements

Roadway Segments

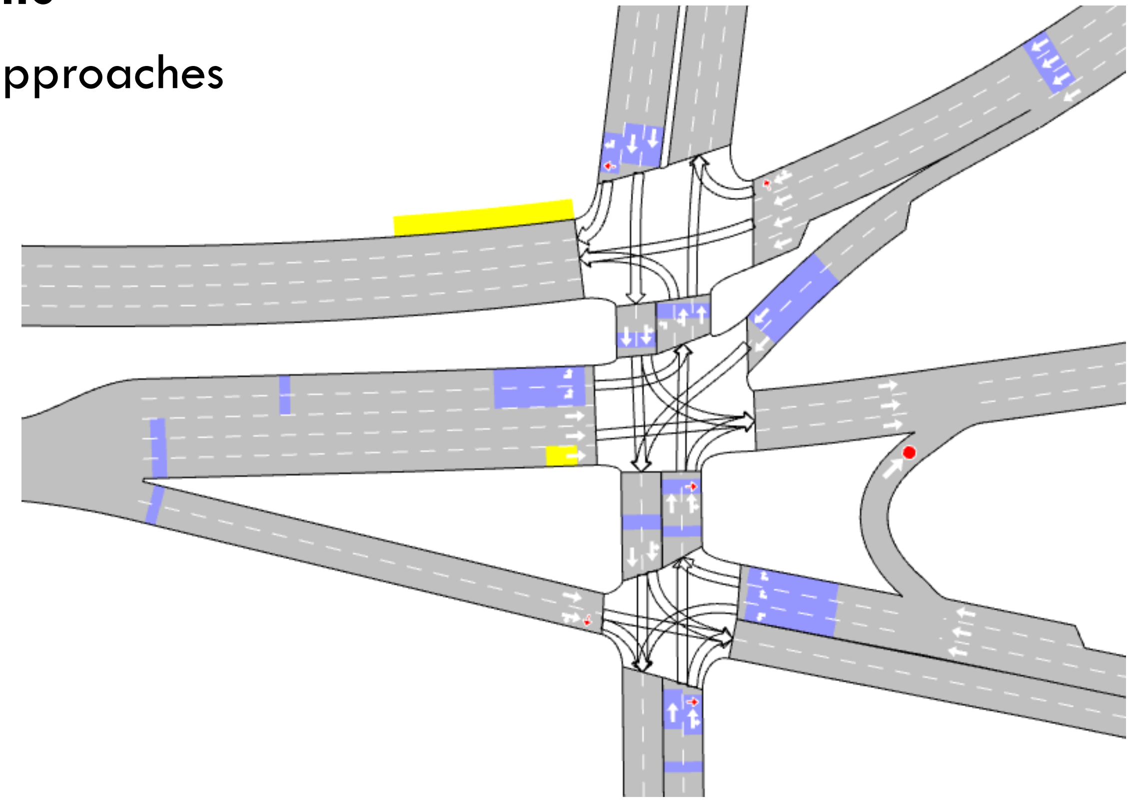
- **Roadway types**
  - Freeways
  - On/Off ramps
  - Arterials
  - Local streets

- **Segment characteristics**
  - Name
  - Speed limits
  - Lane width
  - Lane restrictions
    - HOV
    - Truck



Modeling of intersections

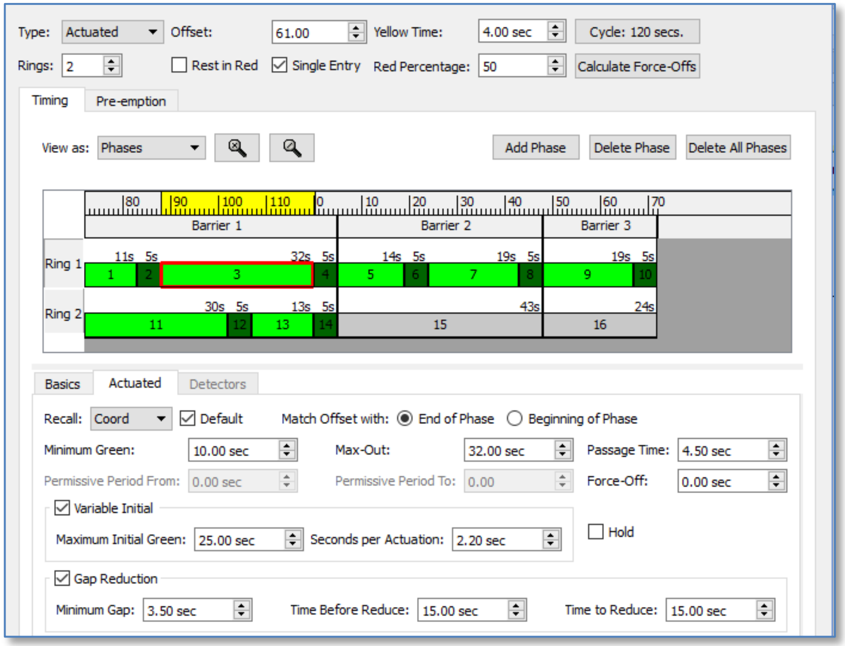
- Intersection movements
  - Lane assignment on approaches
  - Destination lanes
  - Yielding movements
  - Right-turn on red
- Turning bays
  - Length
- Traffic detectors
  - Size
  - Location

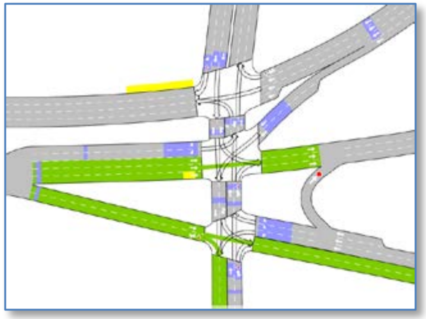


Traffic Signal Control Elements

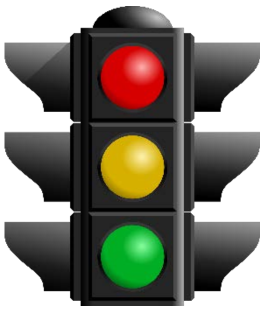
Signal Timing Parameters

- **Basic timing parameters**
  - Cycle length
  - Offset
  - Phase sequence
  - Phase durations
- **Advanced features**
  - Vehicle actuated control
    - Variable initial minimum green
    - Gradual reduction of allowed gap between vehicles to continue green
  - Detector operations
    - Detector calling/extending green
    - Type 3 detectors





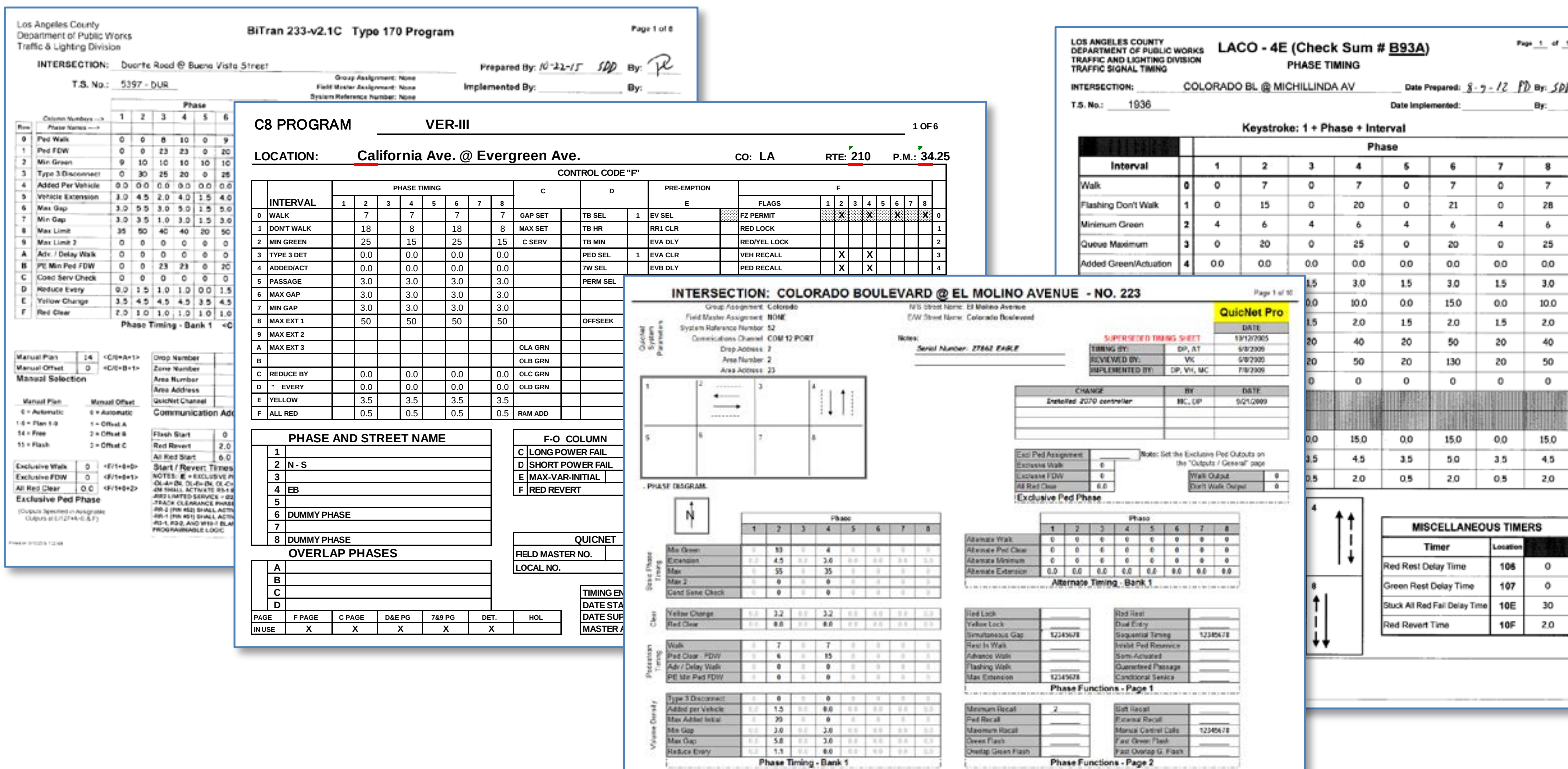
Traffic Signals – Modeling Considerations



- **Fixed-time control is no longer the default control mode**
  - 95+% of intersection in the I-210 corridor are actuated-coordinated
    - Fixed cycle length
    - Phase durations base on vehicle detection
    - Fixed offset point within cycle
  - Real-time control at some intersections
    - SCATS
    - Systems allowing cycle and offset to be changed every 30 minutes
- **Replication of specific control algorithms may require the development of Application Programming Interface modules**

Traffic Signals – Modeling Considerations

- Different control programs used by different agencies → Need to develop a uniform modeling framework

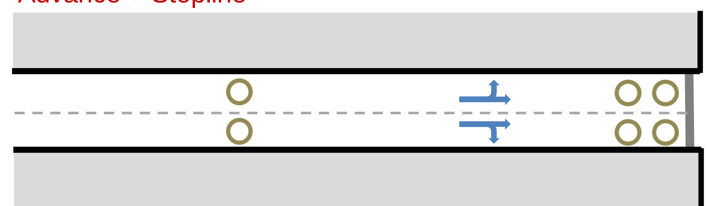


Traffic Signals – Modeling Considerations

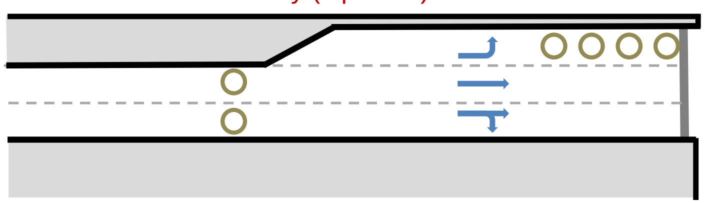
- **Several types of detector configurations used within the corridor both across and within agencies**

Stopline Only

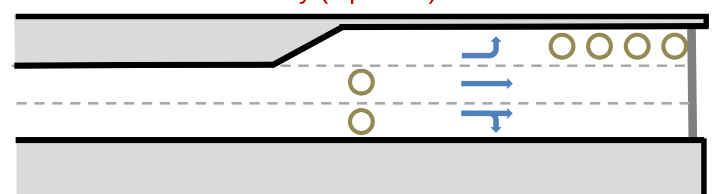
Advance + Stopline



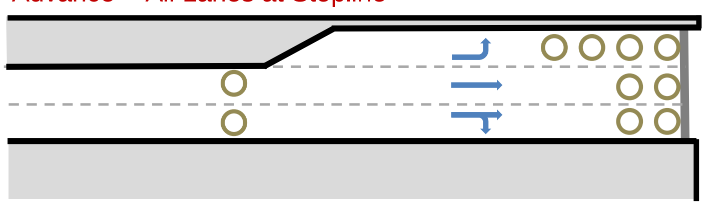
Advance + Left Turn Bay (Option 1)



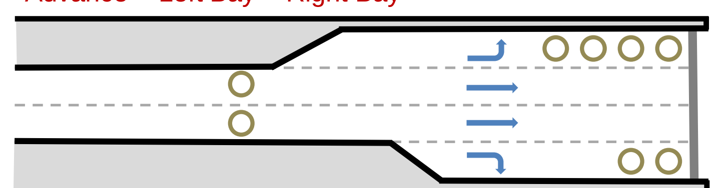
Advance + Left Turn Bay (Option 2)



Advance + All Lanes at Stopline



Advance + Left Bay + Right Bay



Traffic Signals – Modeling Considerations

- **How to organize timing data to facilitate maintenance**
  - Big issue if model is to be continuously used
- **Scale of problem**
  - Many intersections use at least 3 different plans
  - Newer 2070 controllers allow up to 64 plans
  - Different timing schedules for week and weekend days
  - Special control schedules for holidays

TABLE 0 - Time Of Day

Event	Hour : Min	Plan or Function	Sun 1	Mon 2	Tue 3	Wed 4	Thu 5	Fri 6	Sat 7
0	00 : 00	E	X	X	X	X	X	X	X
1	06 : 00	2		X	X	X	X	X	
2	09 : 00	1	X	X	X	X	X	X	X
3	15 : 30	3		X	X	X	X	X	
4	19 : 00	1		X	X	X	X	X	
5	21 : 00	E	X	X	X	X	X	X	X
6	:								
7	:								
8	:								
9	:								
A	:								
B	:								
C	:								
D	:								
E	:								
F	:								

TABLE 1 - Time Of Day

Event	Hour : Min	Plan or Function	Sun 1	Mon 2	Tue 3	Wed 4	Thu 5	Fri 6	Sat 7
0	00 : 00	E		X	X	X	X	X	
1	09 : 00	1		X	X	X	X	X	
2	21 : 00	E		X	X	X	X	X	
3	:								
4	:								
5	:								
6	:								
7	:								
8	:								
9	:								
A	:								
B	:								
C	:								
D	:								
E	:								
F	:								

TABLE 6 - Floating Holidays

Event	Month / Day	Table	Sun 1	Mon 2	Tue 3	Wed 4	Thu 5	Fri 6	Sat 7
0	01 / 03	1		X					
1	02 / 03	1		X					
2	05 / 09	1		X					
3	09 / 01	1		X					
4	11 / 04	1					X		
5	/								
6	/								
7	/								
8	/								
9	/								
A	/								
B	/								
C	/								
D	/								
E	/								
F	/								

TABLE 7 - Exception Days

Event	Month / Day	Table	Sun 1	Mon 2	Tue 3	Wed 4	Thu 5	Fri 6	Sat 7
0	01 / 01	1		X	X	X	X	X	
1	01 / 02	1		X					
2	07 / 04	1		X	X	X	X	X	
3	07 / 05	1		X					
4	11 / 10	1						X	
5	11 / 11	1		X	X	X	X	X	
6	11 / 12	1		X					
7	12 / 24	1		X	X	X	X	X	
8	12 / 25	1		X	X	X	X	X	
9	12 / 26	1		X				X	
A	/								
B	/								
C	/								
D	/								
E	/								
F	/								

Traffic Signals – Modeling Considerations

- **Example: Schedule of active timing plans from I-210 corridor**

Intersection – WEEK

Main Street	Cross Street	0:00	5:00	5:30	6:00	6:15	6:30	6:45	7:00	7:15	7:30	8:00	8:15	8:30	9:00	9:30	11:00	11:30	13:30	14:00	14:30	14:45	15:00	15:30	15:45	16:00	16:15	16:30	17:00	18:00	18:15	19:00	19:15	19:30	20:00	21:00	22:00	22:45	23:00	0:00
Fair Oaks Ave	Painter Street	62	62	62	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	5	5	5	62	62	62	62	62	62
Fair Oaks Ave	Peoria St	62	62	62	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	5	5	5	62	62	62	62	62	62
Fair Oaks Ave	Villa St	62	62	62	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	7	7	5	62	62	62	62	62	62
Fair Oaks Ave	Maple St	E	E	E	1	1	1	1	1	1	1	1	1	1	1	5	2	2	2	3	3	3	3	3	3	3	4	4	4	4	4	5	5	5	E	E	E	E	E	E
Fair Oaks Ave	Corson St	E	E	E	1	1	1	1	1	1	1	1	1	1	1	5	2	2	2	3	3	3	3	3	3	3	4	4	4	4	4	5	5	5	E	E	E	E	E	E
Fair Oaks Ave	Valley St	14	14	14	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	7	7	5	14	14	14	14	14	14
Fair Oaks Ave	Congress St	14	14	14	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	5	5	5	14	14	14	14	14	14
Fair Oaks Ave	Fillmore St	14	14	14	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	5	5	5	14	14	14	14	14	14
Fair Oaks Ave	Bellefontaine St	14	14	14	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	5	5	5	14	14	14	14	14	14
Fair Oaks Ave	Glenarm St	14	14	14	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	5	5	5	14	14	14	14	14	14
Arroyo Pkwy	Colorado Blvd	14	14	14	1	1	1	1	1	1	1	1	1	1	1	5	2	2	2	3	3	3	3	3	3	3	4	4	4	4	4	5	5	5	14	14	14	14	14	14
Arroyo Pkwy	Green St	14	14	14	1	1	1	1	1	1	1	1	1	1	1	5	2	2	2	3	3	3	3	3	3	3	4	4	4	4	4	5	5	5	14	14	14	14	14	14
Arroyo Pkwy	Cordova St	E	E	E	E	E	1	1	1	1	1	1	1	1	1	5	2	2	2	3	3	3	3	3	3	3	4	4	4	4	4	4	4	5	E	E	E	E	E	E
Arroyo Pkwy	Del Mar Blvd	14	14	14	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	6	6	6	14	14	14	14	14	14
Arroyo Pkwy	Bellevue Dr	14	14	14	6	6	6	6	6	6	6	6	6	6	6	6	4	4	4	4	7	7	7	7	7	7	4	4	4	4	4	5	5	5	14	14	14	14	14	14
Arroyo Pkwy	California Blvd	14	14	14	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	5	5	5	14	14	14	14	14	14
Arroyo Pkwy	Fillmore St	14	14	14	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	14	14	14	14	14	14
Arroyo Pkwy	Glenarm St	14	14	14	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	14	14	14	14	14	14
Raymond Ave	Del Mar Station	14	14	14	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	6	6	6	14	14	14	14	14	14
Raymond Ave	Pico Street	14	14	14	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	5	5	5	14	14	14	14	14	14
Raymond Ave	Fillmore St	14	14	14	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	5	5	5	14	14	14	14	14	14
Raymond Ave	Glenarm St	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Washington Blvd	Lincoln Ave	1	1	1	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1
Washington Blvd	Glen Ave	F	1	1	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1
Washington Blvd	Fair Oaks Ave	E	E	E	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	5	5	5	E	E	E	E	E	E
Washington Blvd	Raymond Ave	E	E	E	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	3	3	3	3	E	E	E	E	E	E	E	E	E	E	E
Washington Blvd	Marengo Ave	E	1	1	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	3	3	3	3	1	1	1	1	1	E	E	E	E	E	E
Washington Blvd	Los Robles Ave	E	E	E	E	E	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	5	5	5	E	E	E	E	E	E
Washington Blvd	El Molino Ave	E	1	1	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	3	3	3	3	1	1	1	1	1	1	1	1	1	1	E
Washington Blvd	Lake Ave	62	62	62	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	5	5	5	62	62	62	62	62	62
Washington Blvd	Catalina Ave	E	E	E	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	5	5	5	E	E	E	E	E	E
Washington Blvd	Hill Ave	E	E	E	E	E	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	5	5	5	E	E	E	E	E	E
Washington Blvd	Sierra Bonita Ave	1	1	1	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1
Washington Blvd	Sinaloa Ave	E	1	1	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	3	3	3	3	1	1	1	1	1	E	E	E	E	E	E
Washington Blvd	Allen Ave	E	E	E	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	5	5	7	7	7	7	5	5	5	5	5	E	E	E	E	E	E
Washington Blvd	Victory Park Entrance	E	E	E	E	E	E	E	E	E	1	1	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2	2	2	2	5	5	5	E	E	E	E	E	E
Lake Ave	Claremont St	E	E	E	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	5	5	5	E	E	E	E	E	E
Lake Ave	Belvidere St	E	E	E	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	5	5	5	E	E	E	E	E	E
Lake Ave	Macy's Crosswalk	E	E	E	6	6	6	6	6	6	6	6	6	6	6	5	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	5	5	E	E	E	E	E	E
Lake Ave	San Pasqual St	E	E	E	E	E	1	1	1	1	1	1	1	1	1	5	2	2	2	3	3	3	3	3	3	3	4	4	4	4	4	4	5	5	E	E	E	E	E	E
Hill Ave	San Pasqual St	F	F	F	F	F	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	5	5	5	5	5	5	5	5	F
Allen Ave	Casa Grande St	E	E	E	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	5	5	7	7	7	7	5	5	5	5	5	E	E	E	E	E	E
Mountain St / Seco	Lincoln Ave	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
Mountain St	I-210 WB Off Ramp	14	14	14	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	14	14	14	14	14	14
Mountain St	PW-Yard Driveway Entran	62	62	62	62	62	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	62	62	62	62	62	62
Mountain St	Sunset Ave	E	E	E	2	2	2	2	2	2	2	2	2	2	2	5	5	5	5	5	5	5	5	3	3	3	3	3	3	E	E	E	E	E	E	E	E	E	E	E
Mountain St	Fair Oaks Ave	E	E	E	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	5	5	5	E	E	E	E	E	E
Mountain St	Raymond Ave	1	1	1	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1
Mountain St	Marengo Ave	1	1	1	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1
Mountain St	Los Robles Ave	E	E	E	E	E	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	5	5	5	E	E	E	E	E	E
Mountain St	El Molino Ave	1	1	1	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mountain St	Lake Ave	E	E	E	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	5	5	5	E	E	E	E	E	E
Mountain St	Hill Ave	5	5	5	5	5	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	5	5	5	5	5	5	5	5	5
Mountain St	Allen Ave	E	E	E	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	5	5	7	7	7	7	5	5	5	5	5	E	E	E	E	E	E
Altadena Dr	Cooley Pl	E	E	E	E	E	E	E	E	5	5	E	E	E	E	E	E	E	E	E	5	5	5	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Altadena Dr	Paloma St	5	5	5	1	1	1	1	1	1	1	1	1	1	1	5	2	2	3	3	3	3	3	3	3	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5
Sierra Madre Blvd	Sierra Madre Blvd	E	E	E	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	5	5	5	E	E	E	E	E	E
Sierra Madre Villa	Paloma St	E	E	E	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	5	5	5	E	E	E	E	E	E

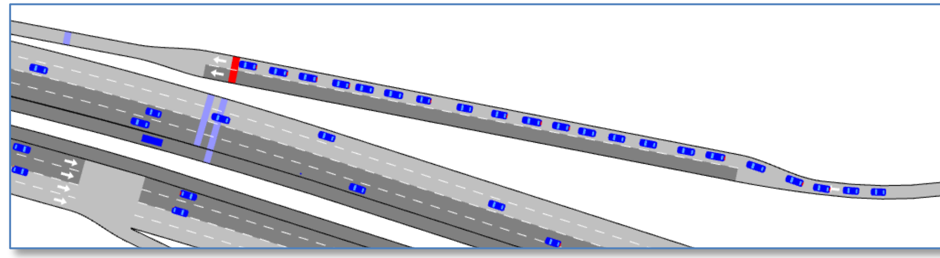
Intersection – WEEKDEND

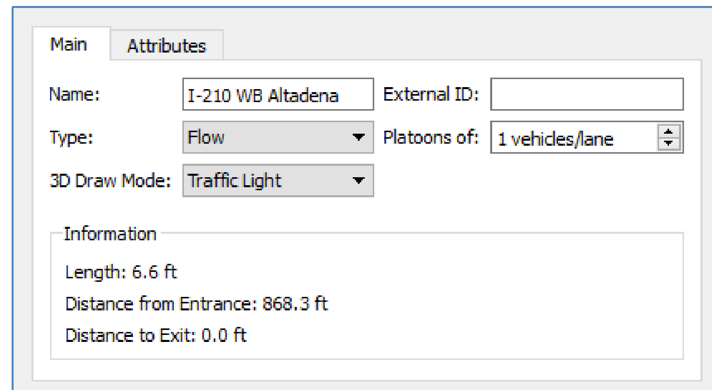
Main Street	Cross Street	0:00	3:00	5:00	6:00	6:30	6:45	8:00	9:00	10:00	10:45	13:00	13:30	18:00	19:00	19:30	20:00	21:00	22:00	22:45	0:00
Fair Oaks Ave	Painter Street	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
Fair Oaks Ave	Peoria St	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
Fair Oaks Ave	Villa St	62	62	62	5	5	5	5	5	5	5	5	5	5	5	5	62	62	62	62	62
Fair Oaks Ave	Maple St	E	E	E	5	5	5	5	5	5	5	5	5	5	5	5	E	E	E	E	E
Fair Oaks Ave	Corson St	E	E	E	5	5	5	5	5	5	5	5	5	5	5	5	E	E	E	E	E
Fair Oaks Ave	Valley St	14	14	14	5	5	5	5	5	5	5	5	5	5	5	5	14	14	14	14	14
Fair Oaks Ave	Congress St	14	14	14	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	14
Fair Oaks Ave	Fillmore St	14	14	14	5	5	5	5	5	5	5	5	5	5	5	5	14	14	14	14	14
Fair Oaks Ave	Bellefontaine St	14	14	14	5	5	5	5	5	5	5	5	5	5	5	5	14	14	14	14	14
Fair Oaks Ave	Glenarm St	14	14	14	5	5	5	5	5	5	5	5	5	5	5	5	14	14	14	14	14
Arroyo Pkwy	Colorado Blvd	14	14	14	5	5	5	5	5	5	5	5	5	5	5	5	14	14	14	14	14
Arroyo Pkwy	Green St	14	14	14	5	5	5	5	5	5	5	5	5	5	5	5	14	14	14	14	14
Arroyo Pkwy	Cordova St	E	E	E	5	5	5	5	5	5	5	5	5	5	5	5	E	E	E	E	E
Arroyo Pkwy	Del Mar Blvd	14	14	14	6	6	6	6	6	6	6	6	6	6	6	6	14	14	14	14	14
Arroyo Pkwy	Bellevue Dr	14	14	14	4	4	4	4	4	4	4	4	4	4	4	4	14	14	14	14	14
Arroyo Pkwy	California Blvd	14	14	14	5	5	5	5	5	5	5	5	5	5	5	5	14	14	14	14	14
Arroyo Pkwy	Fillmore St	14	14	14	6	6	6	6	6	6	6	6	6	6	6	6	14	14	14	14	14
Arroyo Pkwy	Glenarm St	14	14	14	6	6	6	6	6	6	6	6	6	6	6	6	14	14	14	14	14
Raymond Ave	Del Mar Station	14	14	14	6	6	6	6	6	6	6	6	6	6	6	6	14	14	14	14	14
Raymond Ave	Pico Street	14	14	14	5	5	5	5	5	5	5	5	5	5	5	5	14	14	14	14	14
Raymond Ave	Fillmore St	14	14	14	5	5	5	5	5	5	5	5	5	5	5	5	14	14	14	14	14
Raymond Ave	Glenarm St	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Washington Blvd	Lincoln Ave	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Washington Blvd	Glen Ave	E	E	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	E
Washington Blvd	Fair Oaks Ave	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Washington Blvd	Raymond Ave	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Washington Blvd	Marengo Ave	E	E	1	1	1	1	1	1	1	1	1	1	1	1	1	E	E	E	E	E
Washington Blvd	Los Robles Ave	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Washington Blvd	El Molino Ave	E	E	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	E
Washington Blvd	Lake Ave	E	E	E	5	5	5	5	5	5	5	5	5	5	5	5	E	E	E	E	E
Washington Blvd	Catalina Ave	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Washington Blvd	Hill Ave	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Washington Blvd	Sierra Bonita Ave	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Washington Blvd	Sinaloa Ave	E	E	1	1	1	1	1	1	1	1	1	1	1	1	1	E	E	E	E	E
Washington Blvd	Allen Ave	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Washington Blvd	Victory Park Entrance	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Lake Ave	Claremont St	E	E	E	5	5	5	5	5	5	5	5	5	5	5	5	E	E	E	E	E
Lake Ave	Belvidere St	E	E	E	5	5	5	5	5	5	5	5	5	5	5	5	E	E	E	E	E
Lake Ave	Macy's Crosswalk	E	E	E	5	5	5	5	5	5	5	5	5	5	5	5	E	E	E	E	E
Lake Ave	San Pasqual St	E	E	E	5	5	5	5	5	5	5	5	5	5	5	5	E	E	E	E	E
Hill Ave	San Pasqual St	F	F	F	5	5	5	5	5	5	5	5	5	5	5	5	5	5	E	E	F
Allen Ave	Casa Grande St	E	E	E	E	E	E	E	5	5	5	5	5	5	5	5	E	E	E	E	E
Mountain St / Seco	Lincoln Ave	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
Mountain St	I-210 WB Off Ramp	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Mountain St	PW-Yard Driveway Entran	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
Mountain St	Sunset Ave	E	E	E	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	E
Mountain St	Fair Oaks Ave	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Mountain St	Raymond Ave	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mountain St	Marengo Ave	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mountain St	Los Robles Ave	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Mountain St	El Molino Ave	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mountain St	Lake Ave	E	E	E	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	E
Mountain St	Hill Ave	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Mountain St	Allen Ave	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Altadena Dr	Cooley Pl	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Altadena Dr	Paloma St	E	E	E	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	E
Sierra Madre Blvd	Sierra Madre Blvd	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Sierra Madre Villa	Paloma St	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E

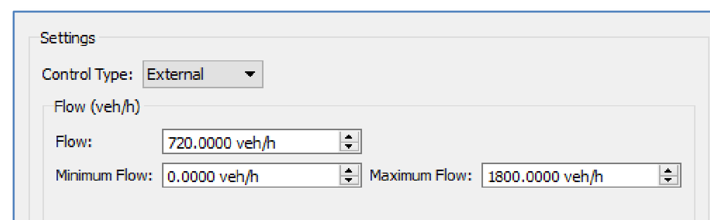
Ramp Metering Elements

Ramp Metering

- **Type of metering control**
  - Fixed
  - Time-of-day
  - Variable based on mainline vehicle detections
- **Basic control parameters**
  - Min/Max flow rate
  - Number of vehicles per green
  - Associated detectors

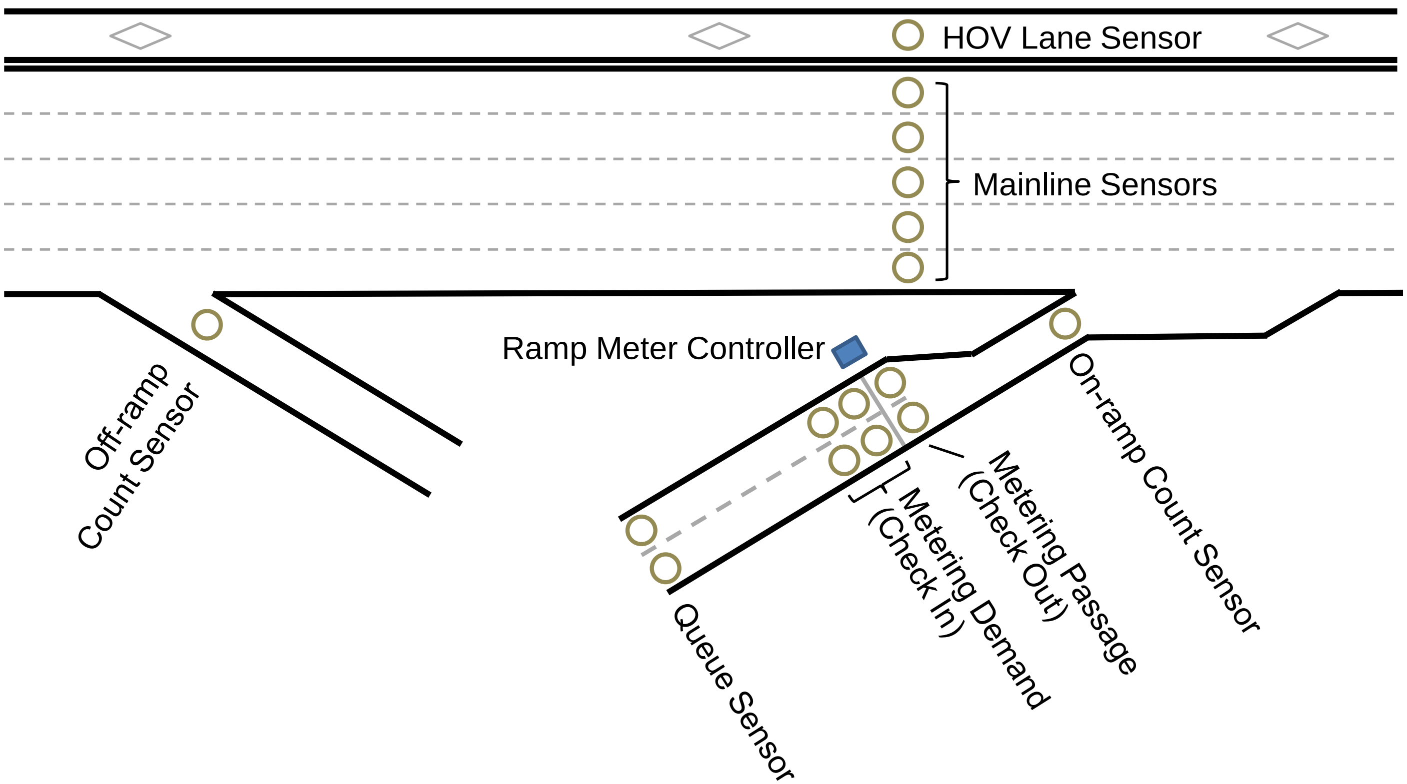






Ramp Metering Detectors

- Typical detector configuration



Ramp Metering – Modeling Considerations

- Ramp metering schedule
- Variations in metering operations across ramps

I-210 Ramp Metering Rate Schedule

Freeway	Ramp	Milepost	0:00	0:30	1:00	1:30	2:00	2:30	3:00	3:30	4:00	4:30	5:00	5:30	6:00	6:30	7:00	7:30	8:00	8:30	9:00	9:30	10:00	10:30	11:00	11:30
I-210 EB	Marengo	25.74																								
	Lake	26.49																								
	Hill	27.16																								
	Allen	27.67																								
	San Gabriel	28.70																								
	Sierra Madre Villa	29.46																								
	Rosemead	29.74																								
	Michillinda	30.01																								
	Baldwin	30.95																								
	Santa Anita	32.06																								
	Huntington WB	32.86																								
	Huntington EB	32.86																								
	Myrtle	34.15																								
	Mountain	35.12																								
	Buena Vista	36.36																								
	Mount Olive	36.33																								
	I-605 Connector	36.60																								
	Irwindale	37.92																								
	Vernon	39.05													10	10	10	10	10	10	10	10	10	10	10	10
	Azusa SB	39.55													10	10	10	10	10	10	10	10	10	10	10	10
	Azusa NB	39.64													10	10	10	10	10	10	10	10	10	10	10	10
	Citrus SB	40.56													10	10	10	10	10	10	10	10	10	10	10	10
	Citrus NB	40.70													10	10	10	10	10	10	10	10	10	10	10	10
I-210 WB	Lake	26.14											14	14	14	14	14	14	14	14	14	14	14	14	14	14
	Hill	26.82											12	12	12	12	12	12	12	12	12	12	12	12	12	12
	Altadena	28.05											10	10	10	10	10	12	12	10	10	10	10	10	10	10
	San Gabriel	28.29											10	10	10	10	10	12	12	10	10	10	10	10	10	10
	Sierra Madre Villa	29.19											5	5	5	5	9	9	9	9	6	6	6	6	6	6
	Rosemead SB	29.59											10	10	10	10	10	10	10	10	10	10	10	10	10	10
	Rosemead/Foothill	29.71											10	10	10	10	12	12	12	12	10	10	10	10	10	10
	Michillinda	29.85											10	10	10	10	12	12	12	12	10	10	10	10	10	10
	Baldwin (North)	30.49											10	10	10	10	12	12	10	10	10	10	10	10	10	10
	Baldwin	30.49											10	10	10	10	10	10	10	10	10	10	10	10	10	10
	Santa Anita SB	31.73											10	10	10	10	10	10	10	10	10	10	10	10	10	10
	Santa Anita NB	31.91											10	10	10	10	10	10	10	10	10	10	10	10	10	10
	Huntington	32.76											10	10	10	10	10	10	10	10	10	10	10	10	10	10
	Myrtle	32.76											10	10	10	10	10	10	10	10	10	10	10	10	10	10
	Mountain	34.61											10	10	10	10	10	10	10	10	10	10	10	10	10	10
	Buena Vista	35.12											10	10	10	10	10	10	10	10	10	10	10	10	10	10
	I-605 Connector	36.00											32	32	30	30	30	30	30	30	30	32	32	32		
	Mount Olive	36.30											10	10	10	10	10	10	10	10	10	10	10	10		
	Irwindale SB	37.78											10	10	10	10	10	10	10	10	10	10	10	10		
	Irwindale NB	37.92											10	10	10	10	10	10	10	10	10	10	10	10		
	Vernon	38.87											10	10	10	10	10	10	10	10	10	10	10	10		
	Azusa SB	39.52											5	5	7	7	7	7	5	5	5	5	5	5		
	Azusa NB	39.62											10	10	18	18	18	18	10	10	10	10	10	10		
	Citrus NB	40.70											10	10	10	10	10	10	10	10	10	10	10	10		

Freeway	Ramp	Milepost	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30
I-210 EB	Marengo	25.74	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12							
	Lake	26.49	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12							
	Hill	27.16	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
	Allen	27.67	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
	San Gabriel	28.70	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
	Sierra Madre Villa	29.46	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
	Rosemead	29.74	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
	Michillinda	30.01	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
	Baldwin	30.95	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
	Santa Anita	32.06	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
	Huntington WB	32.86	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5							
	Huntington EB	32.86	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
	Myrtle	34.15	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
	Mountain	35.12	10	10	10	10	10	10	10	10	10	14	14	14	10	10	10	10	10							
	Buena Vista	36.36	10	10	10	10	10	10	10	10	10	14	14	14	10	10	10	10	10							
	Mount Olive	36.33	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
	I-605 Connector	36.60	34	34	34	34	34	32	32	32	32	32	32	32	32	32	34	34	34							
	Irwindale	37.92	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
	Vernon	39.05	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
	Azusa SB	39.55	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
	Azusa NB	39.64	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
	Citrus SB	40.56	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
	Citrus NB	40.70	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
I-210 WB	Lake	26.14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14							
	Hill	26.82	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12							
	Altadena	28.05	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
	San Gabriel	28.29	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
	Sierra Madre Villa	29.19	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6							
	Rosemead SB	29.59	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
	Rosemead/Foothill	29.71	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
	Michillinda	29.85	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
	Baldwin (North)	30.49	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
	Baldwin	30.49	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
	Santa Anita SB	31.73	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
	Santa Anita NB	31.91	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
	Huntington	32.76	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
	Myrtle	32.76	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12							
	Mountain	34.61	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
	Buena Vista	35.12	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10							
	I-605 Connector	36.00																								
	Mount Olive	36.30																								
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	Irwindale NB	37.92																								
	Vernon	38.87																								
	Azusa SB	39.52																								
	Azusa NB	39.62																								
	Citrus NB	40.70																								

Ramp Metering – Modeling Considerations

- **Custom APIs required for modeling non-basic ramp metering operations**
  - Queue overrides
  - Mainline congestion override
  - Dynamic metering algorithms
    - Linear Mainline Responsive (LMR)
    - SWARM
    - Fuzzy Logic
    - HERO
    - Etc.

```python
def setCurrentScheduledMeterRate(ArrayPos, MeterID, ChangeCode, TODRate, timeSta, acycle):
    if (TODRate > 0):
        #ramp metering rate defined for period of day
        if(ControlOption[ArrayPos] == 1):
            #-------------------------
            #control option set to LMR
            #-------------------------
            PlanType = getCurrentPlanType(timeSta, MeterID)
            CriticalOccup = CriticalOccupA[ArrayPos]
            CriticalVolume = CriticalVolumeA[ArrayPos]
            if (PlanType == "B"):
                CriticalOccup = CriticalOccupB[ArrayPos]
                CriticalVolume = CriticalVolumeB[ArrayPos]

            if(Avg1MinMainDetOccup[ArrayPos] < CriticalOccup):
                #1-min average mainline occupancy < critical occupancy
                LMRRate = (NumMainDets[ArrayPos] * (CriticalVolume - Avg3MinMainDetLaneVolume[ArrayPos])/3.) * 60.
                if(LMRRate < TODRate):
                    LMRRate = TODRate

                if(LMRRate > RateMax[ArrayPos]):
                    #LMR rate greater than maximum metering rate permissible --> go to full green
                    GreenBallMeterRate = NumMeteringLanes[ArrayPos] * GreenBallRate
                    Error = ECIChangeParametersFlowMeteringById(MeterID, timeSta, GreenBallMeterRate,
                                                                GreenBallMeterRate, RateMin[ArrayPos], timeSta, acycle)
                else:
                    #LMR rate is within permitted values --> implement calculated value
                    Error = ECIChangeParametersFlowMeteringById(MeterID, timeSta, RateMax[ArrayPos], LMRRate,
                                                                RateMin[ArrayPos], timeSta, acycle)
            else:
                #1-minute average mainline occupancy >= critical occupancy ---> implement TOD rate
                Error = ECIChangeParametersFlowMeteringById(MeterID, timeSta, RateMax[ArrayPos], TODRate,
                                                            RateMin[ArrayPos], timeSta, acycle)

        elif (ControlOption[ArrayPos] == 0):
            #--------------------------------
            #control option set to TOD control
            #--------------------------------
            if(ChangeCode):
                Error = ECIChangeParametersFlowMeteringById(MeterID, timeSta, RateMax[ArrayPos], TODRate,
                                                            RateMin[ArrayPos], timeSta, acycle)
        else:
            #---------------------------------
            #default control option: TOD control
            #---------------------------------
            if(ChangeCode):
                Error = ECIChangeParametersFlowMeteringById(MeterID, timeSta, RateMax[ArrayPos], TODRate,
                                                            RateMin[ArrayPos], timeSta, acycle)
    else:
        if(ChangeCode):
            # no ramp metering rate defined for period of day --> set meter to green
            GreenBallMeteringRate = NumMeteringLanes[ArrayPos] * GreenBallRate
            Error = ECIChangeParametersFlowMeteringById(MeterID, timeSta, GreenBallMeteringRate, GreenBallMeteringRate,
                                                        RateMin[ArrayPos], timeSta, acycle)
```

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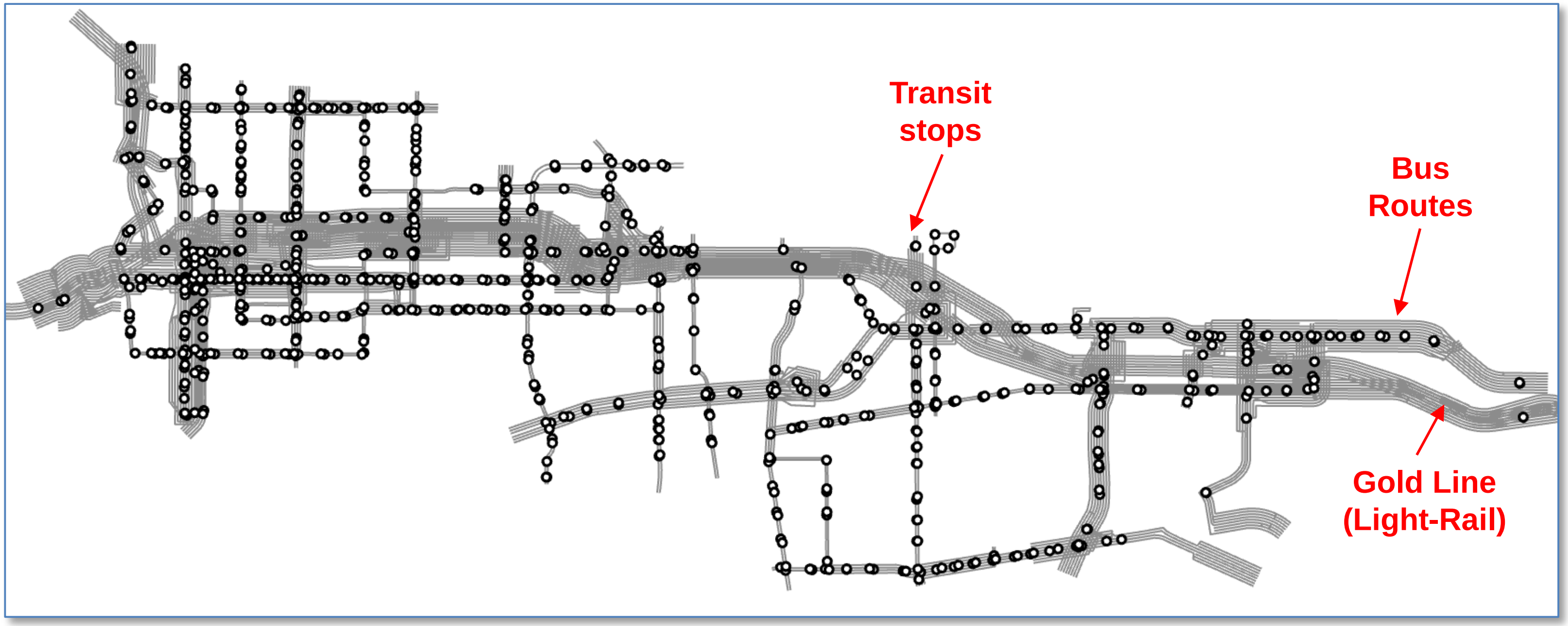
Transit Services

Transit Modeling Needs

- **Simulate impacts on vehicular traffic**
  - Bus stopping on road
  - Signal priority/preemption
- **Simulate impacts of incidents on bus operation**
  - Delays due to congestion
- **Simulate responses to incidents with transit component**
  - Changes in transit service

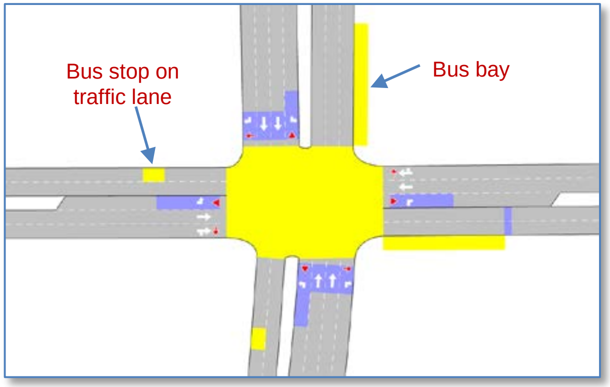
Transit Services Modeled

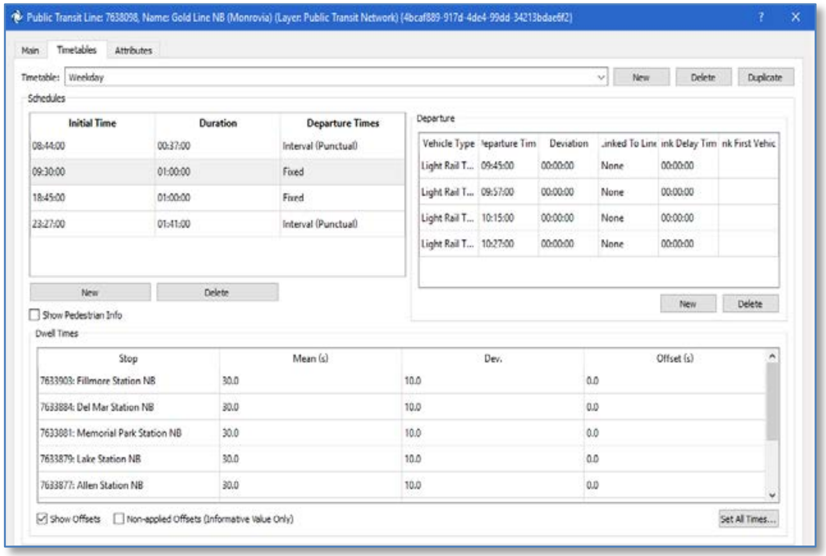
- Metro Gold Line
- Express and local bus routes
  - Metro Bus *(18)*, Foothill Transit *(5)*, LA DOT *(1)*, Pasadena Transit *(9)* Arcadia Transit *(3)* and Duarte Transit *(2)*



Transit Modeling

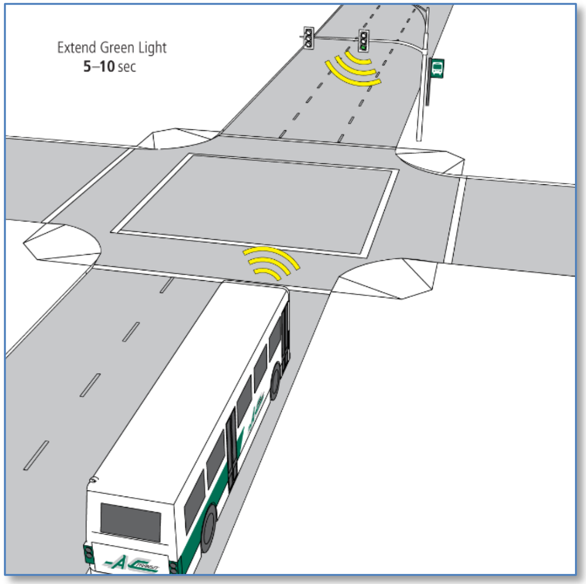
- **Location of bus stops**
- **Types of stop**
  - Bus stopping in the roadway
  - Bus bays
- **Service timetables**
  - Weekday / Saturday / Sunday departure tables
  - Vehicle type used on each run
- **Dwell times**
  - Average time stopped at each service point
    - 20 s average duration
    - 10 s variance
  - Can be adjusted where field observations are available





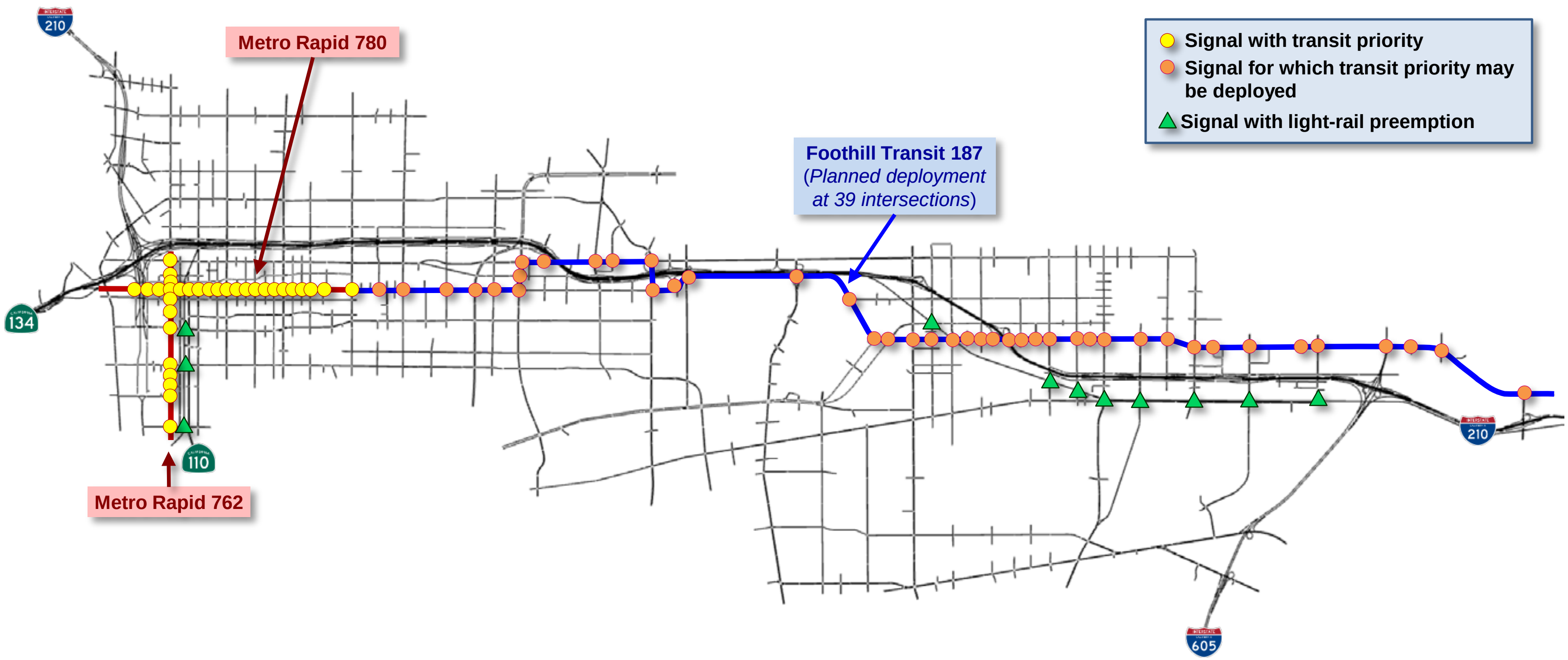
Transit Signal Priority/Preemption

- **Definitions**
  - Preemption: Force change in signal operations
  - Priority: Change in signal operations if signal operational constraints allow it
- **Modeling needs**
  - Simulation of signal preemption required at light-rail crossings to adequately capture corridor operations
    - 11 at-grade crossings
    - Interruptions every 3 minutes during peak hours
  - Corridor stakeholders interested in testing bus priority at several intersections



Transit Signal Priority/Preemption

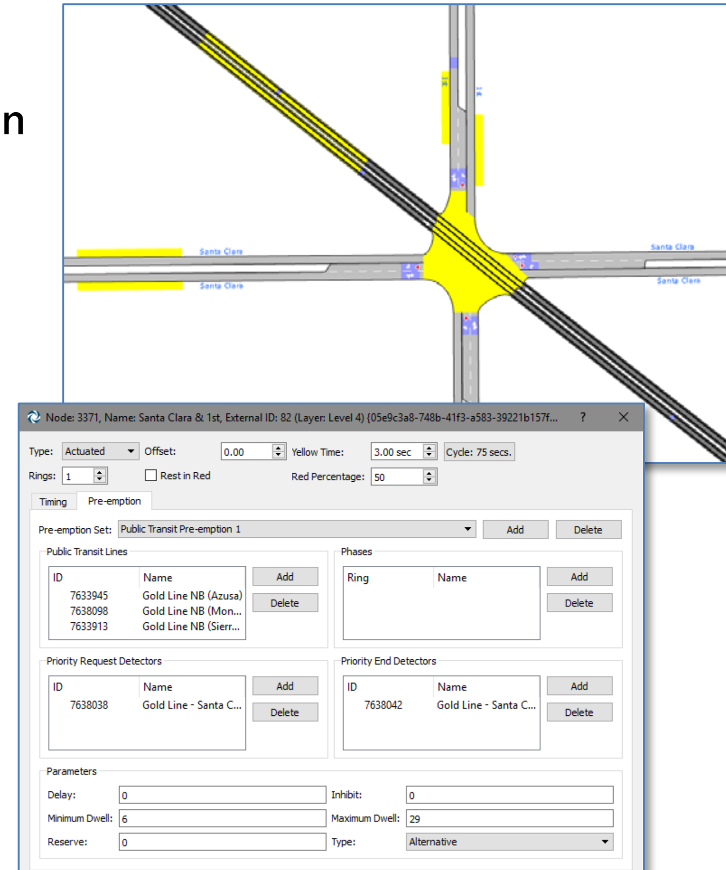
- Existing/proposed intersections with priority/preemption control



Caltrans Metro Foothill Transit SGVCOG California PATH

Transit Signal Priority/Preemption

- **Modeling tasks**
  - Basic priority logic available in Aimsun
  - Light-rail preemption not available
    - Can use existing logic as approximation
    - Cannot force signal to terminate before minimum green ends
    - Need to develop an API

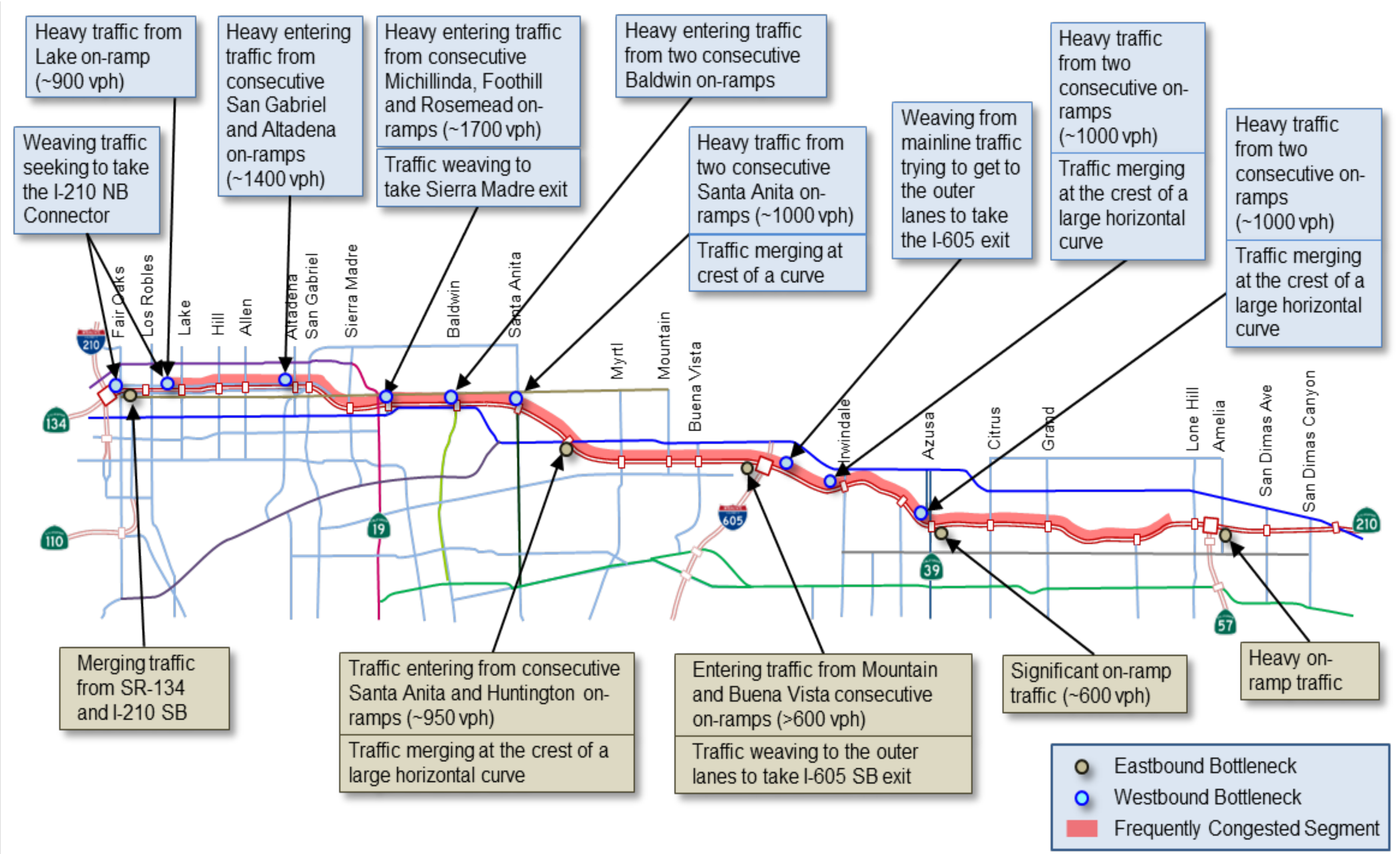


Calibration Approach

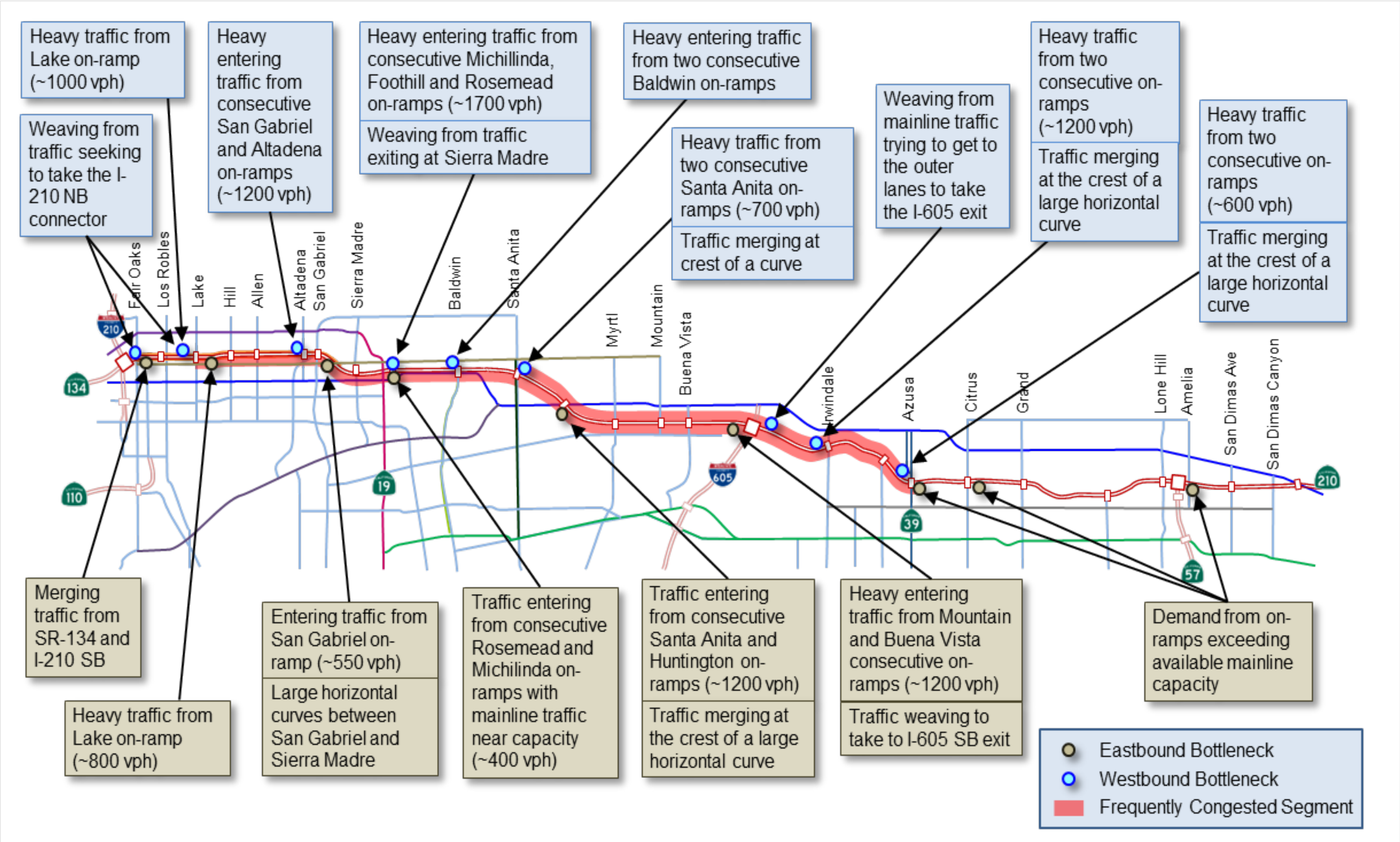
Calibration Objective

- **Simulation of representative traffic volumes on freeway and arterials for time period considered**
- **Replication of bottlenecks on freeway**
  - Location
  - Speed
  - Extent
- **Replication of observed queuing at intersections**
  - Observed approach speeds
  - Location of queues
  - Queue extent

Operational Assessment – AM Peak

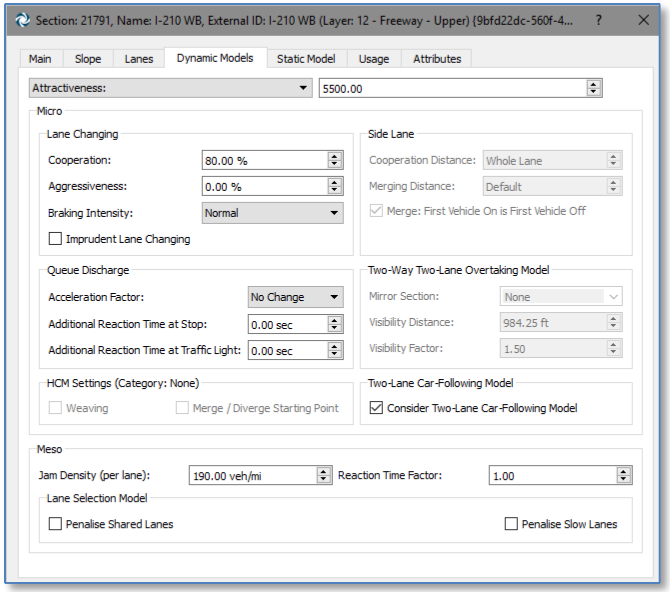


Operational Assessment – PM Peak



Aimsun Calibration Elements

- **Vehicle characteristics**
  - Average vehicle length
- **Driver behavior**
  - Reaction time
  - Speed acceptance
  - Desired gap between vehicles
  - Aggressiveness in accepting short gaps
  - Lane change cooperation
  - Braking intensity
  - etc.

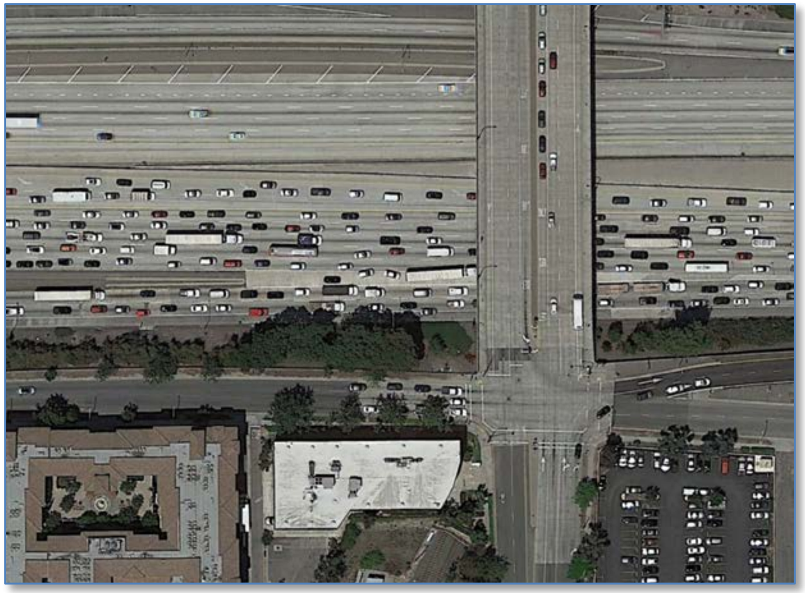


Caltrans Metro SGVCOG Foothill Transit PATH

Calibration Data Sources

- **Data from traffic sensors**
  - Traffic volumes
  - Turning counts
  - Observed speeds
  - Detector occupancy
- **Data from traffic studies**
  - Observed volumes
  - Turning counts
- **Aerial imagery**
  - Vehicle length
  - Spacing between vehicles
- **Probe vehicle data**
  - Travel time data
  - Observed paths

April 2014 – Congestion on I-210 due to major accident



Metro

Existing Calibration Guidelines

- **Existing guidelines for calibrating microscopic models**
  - Cover relatively well calibration of freeways
  - Easily applied to small networks

FHWA Calibration Guidelines

Measure	Calibration Criteria	Acceptance Target
Modeled link flows	Individual link flows: • Flow within 100 vph for links with < 700 vph • Flow within 15% for links with 700 to 2700 vph • Flow within 400 vph for links with > 2700 vph • GEH statistic < 5 Sum of all link flows: • Flow within 5% • GEH < 4	> 85% of cases > 85% of cases > 85% of cases > 85% of cases For all link counts For all link flows
Modeled travel Times	Journey times within network: • Within 15% or 1 minute, whichever criterion is higher	> 85% of cases
Visual Audits	Individual link speeds: • Visually acceptable speed-flow relationships Bottlenecks: • Visually acceptable queuing	To analyst's satisfaction To analyst's satisfaction

$$GEH = \sqrt{\frac{(E-V)^2}{0.5\,(E+V)}}$$

E = Model estimated volumes
V = Field counts

Existing Calibration Guidelines

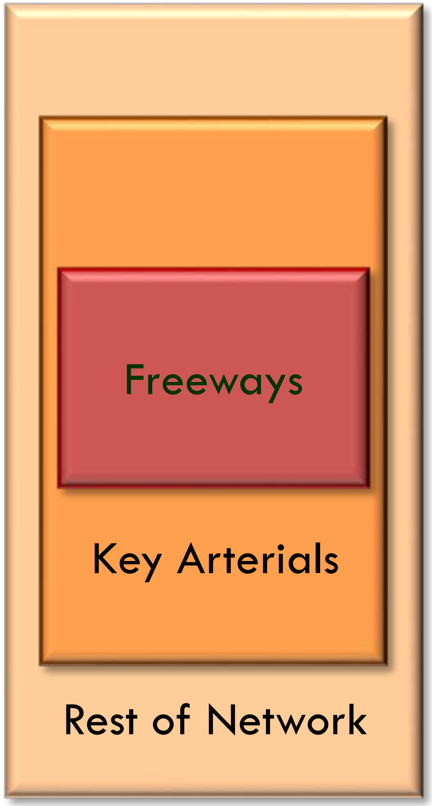
- **Items to consider**
  - Vagueness of "*to analyst's satisfaction*" criterion
  - Availability of reliable data to support the calibration
    - Problem particularly acute for arterials
  - Inherent variability of arterials traffic
    - Traffic entering/leaving arterials between intersections
    - Natural variability of arterial traffic flows
    - Ability for motorists to easily change route

Emerging Guidelines: Cluster-based Analysis

- **Control for time-variant outliers**
  - Simulated day stays within a confidence interval defined by the cluster
- **Control for time-variant "inliers"**
  - Match spatio-temporal critical points such as
    - lowest observed speeds
    - outflow at active bottlenecks
- **Bounded dynamic absolute error**
  - Average error between simulated and representative days should be less than error between the representative day and all days in cluster
- **Bounded systematic error**
  - Simulated day does not provide systemically biased results

Calibration Tiers

- **Detailed calibration of freeways**
  - Flows and speeds on mainline/HOV sections
  - Major bottlenecks
  - Ramp queues
- **Reasonable calibration of key network arterials**
  - Flows and speeds on arterial segments
  - Turning proportions at key intersections
  - Queues at key intersections
- **Rough calibration of arterials at edge of network**
  - Observed flows
  - No unusual congestion at main intersections



Proposed Calibration Guidelines

Freeway elements

Measure	Calibration Criteria	Acceptance Target
Link flows	Individual link flows: • Links with < 700 vph → Within 100 vph • Links with 700 to 2700 vph → Within 15% • Link with > 2700 vph → Within 400 vph • GEH statistic < 5 Sum of all link flows: • Total flow within 5% • GEH < 4	 > 85% of links > 85% of links > 85% of links > 85% of links Over all links Over all links
Travel Times	Travel times along key freeway segments: • Within 15% or 1 minute, whichever is higher	> 85% of cases
Recurrent Bottlenecks	Location: • Front within 0.50 mile • Extent within 0.50 mile Time of occurrence: • Start time within 30 min of observed start • End time within 30 min of observed end	 > 85% of cases* > 85% of cases* > 85% of cases* > 85% of cases*

* All key major bottlenecks must fall within the 85% accepted cases

$$GEH = \sqrt{\frac{(E-V)^2}{0.5\,(E+V)}}$$

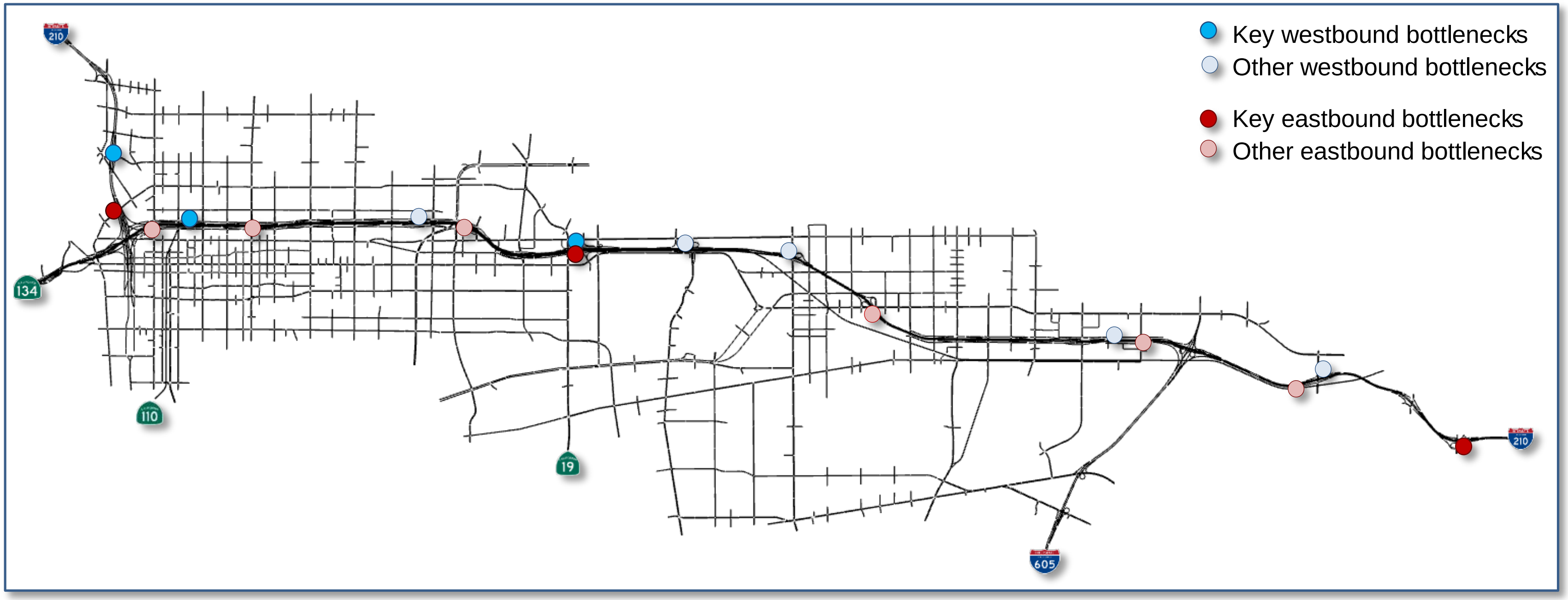
E = Model estimated volumes
V = Field counts

QUESTION: most freeway segments in corridor carry 6000-7000 veh/hr → 400 veh/hr criterial would impose a 5-6% max error

→ Acceptable?

Proposed Calibration Guidelines

- Main corridor freeway bottlenecks



Proposed Calibration Guidelines

- Arterials

Measure	Calibration Criteria	Acceptance Target
Link flows	Individual link flows: • Links with < 700 vph → Within 100 vph • Links with 700 to 2700 vph → Within 15% • Link with > 2700 vph → Within 400 vph • GEH statistic < 5 Sum of all link flows: • Total flow within 5% • GEH < 4	 > 85% of links > 85% of links > 85% of links > 85% of links Over all links Over all links
Turning Proportions	Turning percentages on intersection approaches • Within 25% of observed percentages	 > 85% of cases*
Travel Times	Travel times between key intersections • Within 15% or 1 minute, whichever is higher	 > 85% of cases*
Congested Intersections	Location: • Queuing at known congested intersections • Extent of queue between typical intersections Time of occurrence: • Start time within 30 min of observed start • End time within 30 min of observed end	 > 85% of cases* > 85% of cases* > 85% of cases* > 85% of cases*

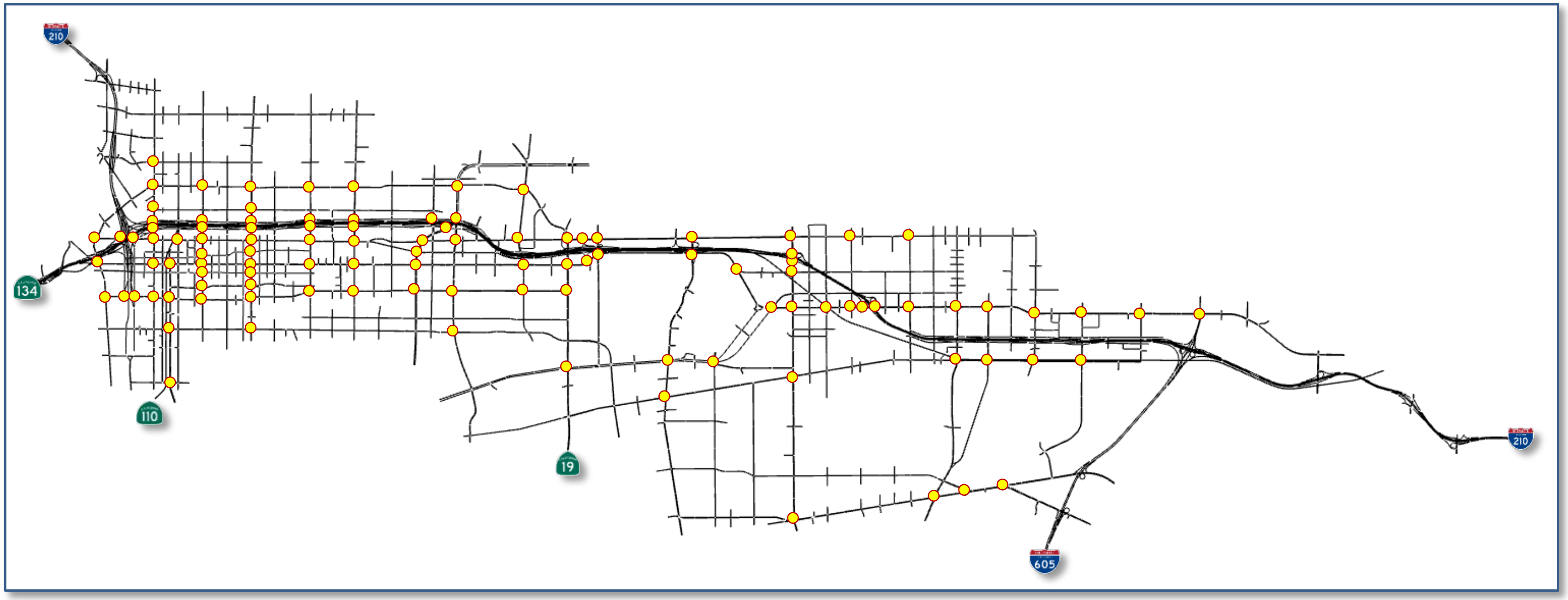
* Over key major intersections

$$GEH = \sqrt{\frac{(E-V)^2}{0.5\,(E+V)}}$$

E = Model estimated volumes
V = Field counts

Proposed Calibration Guidelines

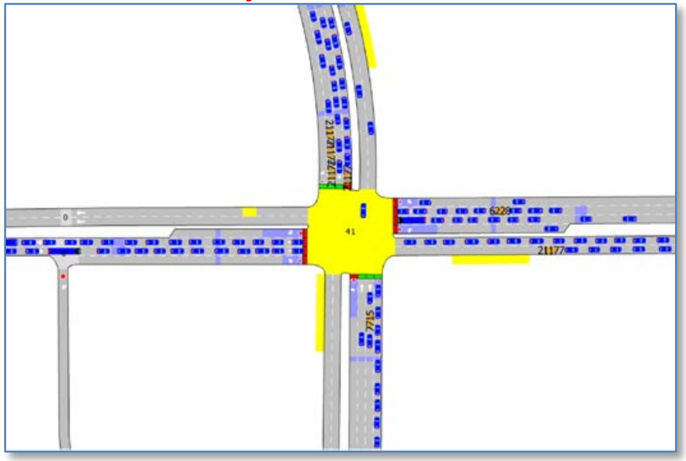
- Key arterial intersections (preliminary list)



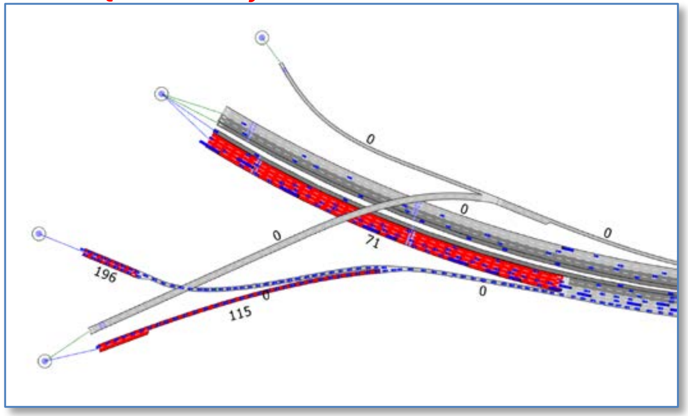
Calibration Steps

- **Step 0 – Error and Validity Testing**
  - Single run tests
    - Check for ODs with non-existent paths
    - Reasonable network loading and emptying
  - Stress tests
    - Unreasonable congestion
    - Virtual queues
    - Missed turns
    - Reasonable route choices

Missed Turns Analysis



Virtual Queue Analysis



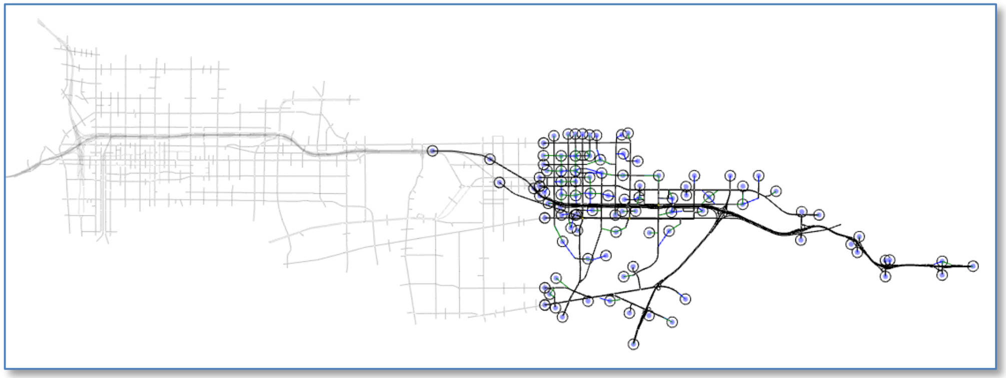
Calibration Steps

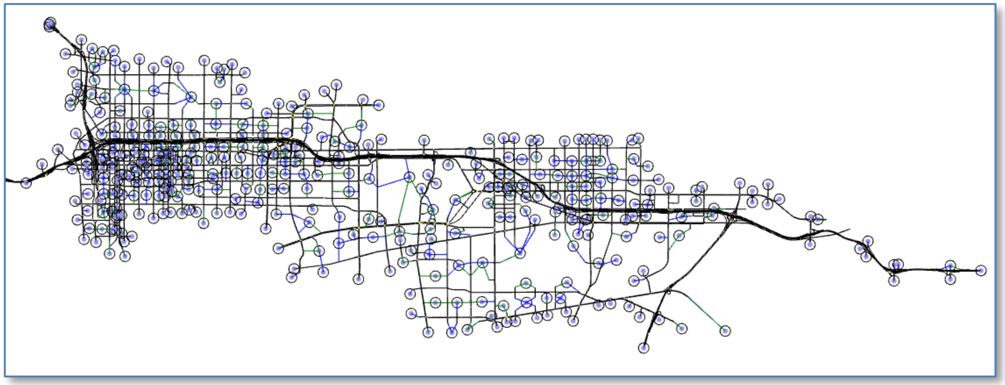
- **Step 1 - Recreate congestion using constant average demand for simulation period**
  - Appropriate vehicle routing decisions
  - Bottlenecks occurring at right location
  - Separate analyses for AM and PM peaks
- **Step 2 - OD matrix adjustment based on observed data**
  - Adjust Car OD matrix using count and turn data
  - Adjust HOV OD matrix using HOV specific data only
- **Step 3 – Recreate congestion using demand profile(s) for each simulation period**
  - Focus on congestion onset, extent, and dissipation

Calibration Steps

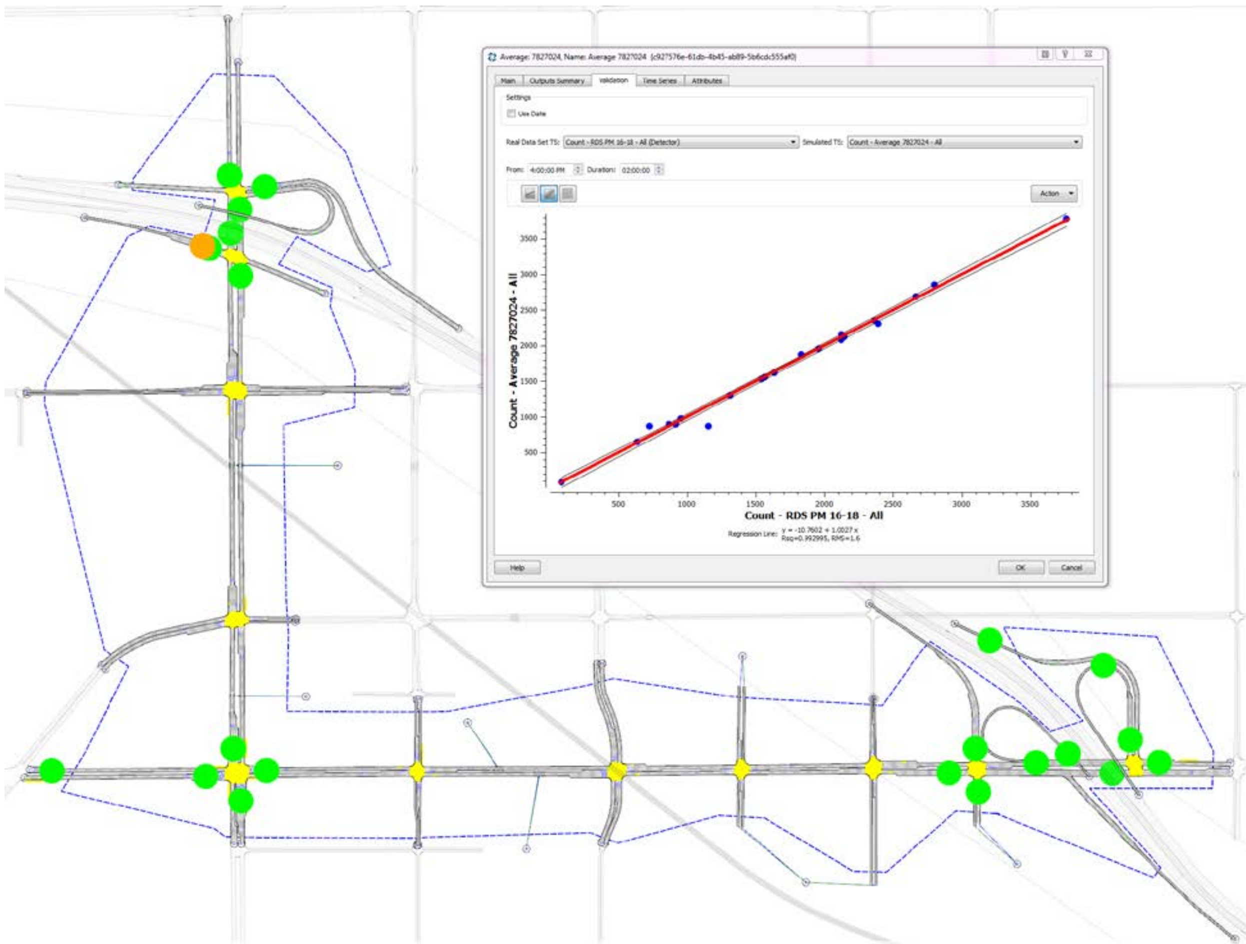
- **Preliminary calibration using small area**
  - Saves time by allowing quicker simulation than full network
  - Global parameters
  - Template for freeway merge/diverge areas
  - Template for congested intersections

- **Full network calibration based on results of small calibration effort**
  - Minor adjustment of global parameters / templates
  - Calibration of local congestion hotspot

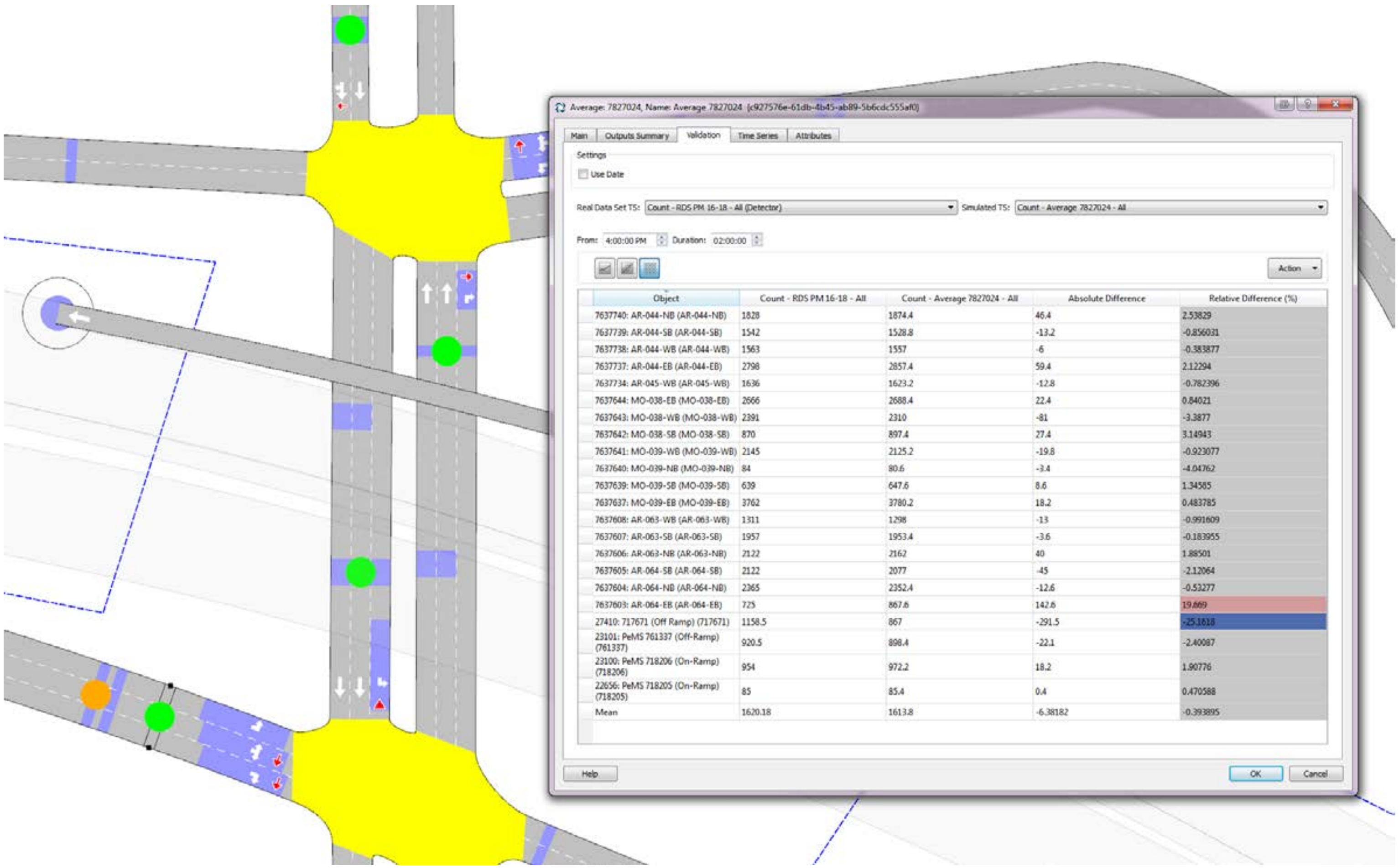




Example Calibration: Santa Anita Reroute



Example Calibration: Santa Anita Reroute



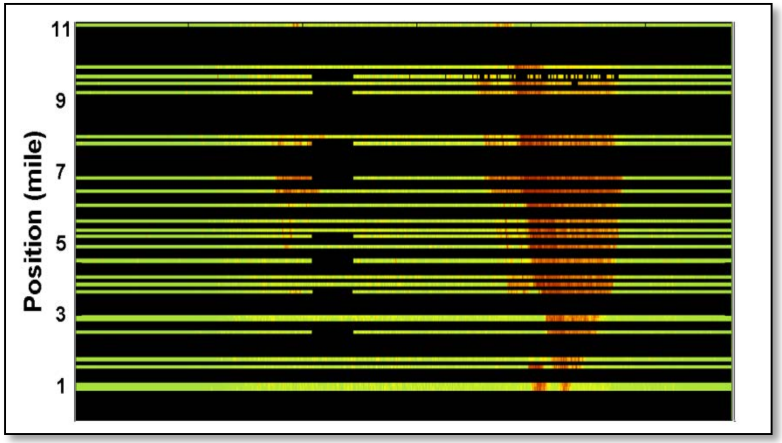
Object	Count - RDS PM 16-18 - All	Count - Average 7827024 - All	Absolute Difference	Relative Difference (%)
7637740: AR-044-NB (AR-044-NB)	1828	1874.4	46.4	2.53829
7637739: AR-044-SB (AR-044-SB)	1542	1528.8	-13.2	-0.856031
7637738: AR-044-WB (AR-044-WB)	1563	1557	-6	-0.383877
7637737: AR-044-EB (AR-044-EB)	2798	2857.4	59.4	2.12294
7637734: AR-045-WB (AR-045-WB)	1636	1623.2	-12.8	-0.782396
7637644: MO-038-EB (MO-038-EB)	2666	2688.4	22.4	0.84021
7637643: MO-038-WB (MO-038-WB)	2391	2310	-81	-3.3877
7637642: MO-038-SB (MO-038-SB)	870	897.4	27.4	3.14943
7637641: MO-039-WB (MO-039-WB)	2145	2125.2	-19.8	-0.923077
7637640: MO-039-NB (MO-039-NB)	84	80.6	-3.4	-4.04762
7637639: MO-039-SB (MO-039-SB)	639	647.6	8.6	1.34585
7637637: MO-039-EB (MO-039-EB)	3762	3780.2	18.2	0.483785
7637608: AR-063-WB (AR-063-WB)	1311	1298	-13	-0.991609
7637607: AR-063-SB (AR-063-SB)	1957	1953.4	-3.6	-0.183955
7637606: AR-063-NB (AR-063-NB)	2122	2162	40	1.88501
7637605: AR-064-SB (AR-064-SB)	2122	2077	-45	-2.12064
7637604: AR-064-NB (AR-064-NB)	2365	2352.4	-12.6	-0.53277
7637603: AR-064-EB (AR-064-EB)	725	867.6	142.6	19.669
27410: 717671 (Off Ramp) (717671)	1158.5	867	-291.5	-25.1618
23101: PeMS 761337 (Off-Ramp) (761337)	920.5	898.4	-22.1	-2.40087
23100: PeMS 718206 (On-Ramp) (718206)	954	972.2	18.2	1.90776
22656: PeMS 718205 (On-Ramp) (718205)	85	85.4	0.4	0.470588
Mean	1620.18	1613.8	-6.38182	-0.393895

Initial State Estimation

Initial State Estimation

- **Information available from input data streams**
  - Vehicle flows on instrumented segments/approaches
  - Vehicle speeds at various locations
  - Travel times between specific locations
  - Detector occupancies
- **Need: Representation of current traffic conditions within the corridor that can be used as a starting point for a simulation**
- **Modeling considerations**
  - How to fill in information gaps?
  - Using a continuous simulation run to produce initial states does not prevent divergences between reality and simulated conditions

Example: Data Gaps in Freeway Speed Data



Method needed to develop estimates of current traffic states and input these states into Aimsun

Initial State for Aimsun Traffic Prediction

- **Inputs**
  - From off-line simulation runs of calibrated model:
    - Library of initial states
    - Distribution of destinations from each link, weighted by flow, obtained via traffic assignment
  - From on-line streaming data:
    - Estimated traffic state on freeway segments
    - Estimated traffic state on arterial routes

- **Adjustment procedure**
  - Modify candidate initial state produced by Aimsun by adding/removing vehicles from each link to match estimated number of vehicles
  - Adjust placement to represent vehicles in queue or approaching a queue

UC Berkeley and TSS are currently working together to implement this functionality

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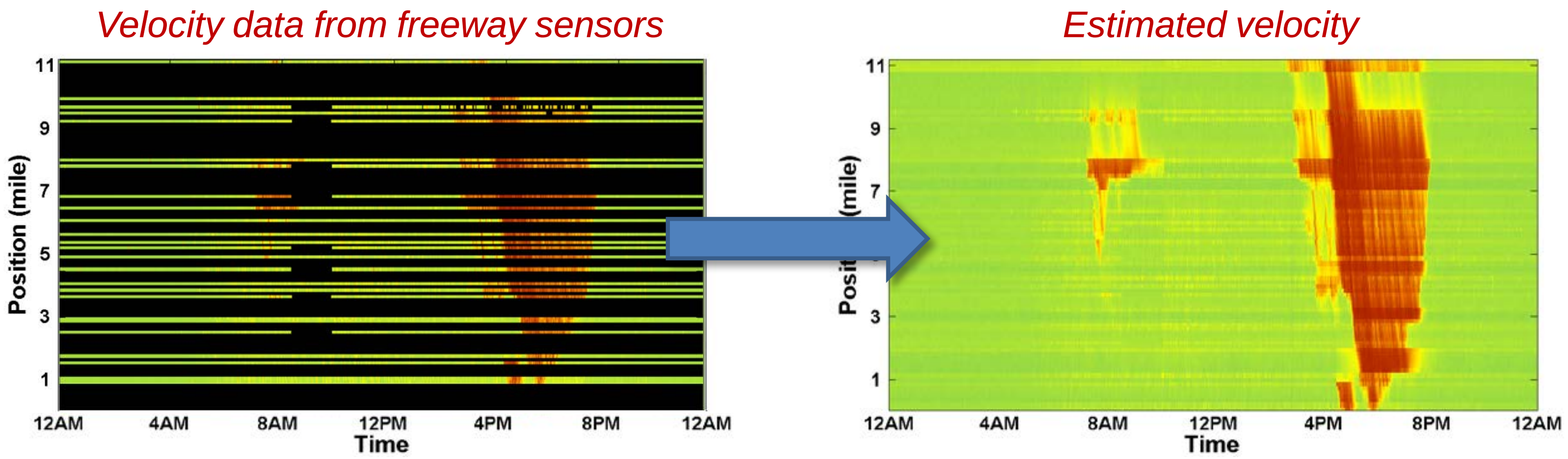
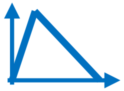
Freeway Estimation Approach

Result of Freeway Estimation

- Real time data exist at specific points along the road
- Estimation fills in the blanks to provide a complete picture of traffic state

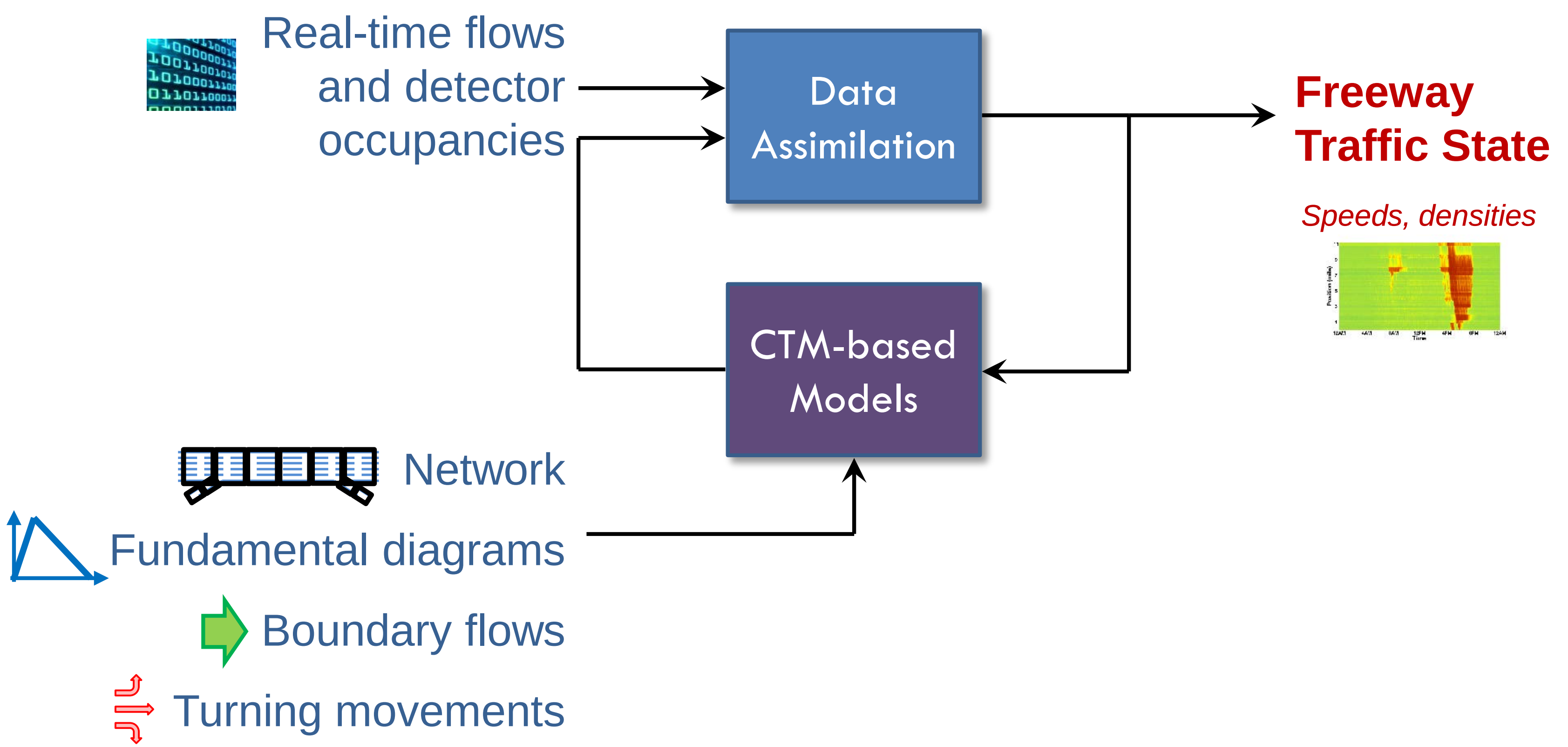


Freeway Traffic Estimation

- **Goal**
  - Provide a complete picture of traffic conditions along a freeway based on observed data
- **Input**
  - Network of roads represented as links and nodes 
  - Fundamental diagrams for each link 
  - Boundary flows at edges of network
  - Turning movements (split ratios) at each node
  - Real-time flows and occupancies from detectors 
- **Output**
  - Velocities and densities on each link

Freeway Traffic Estimation

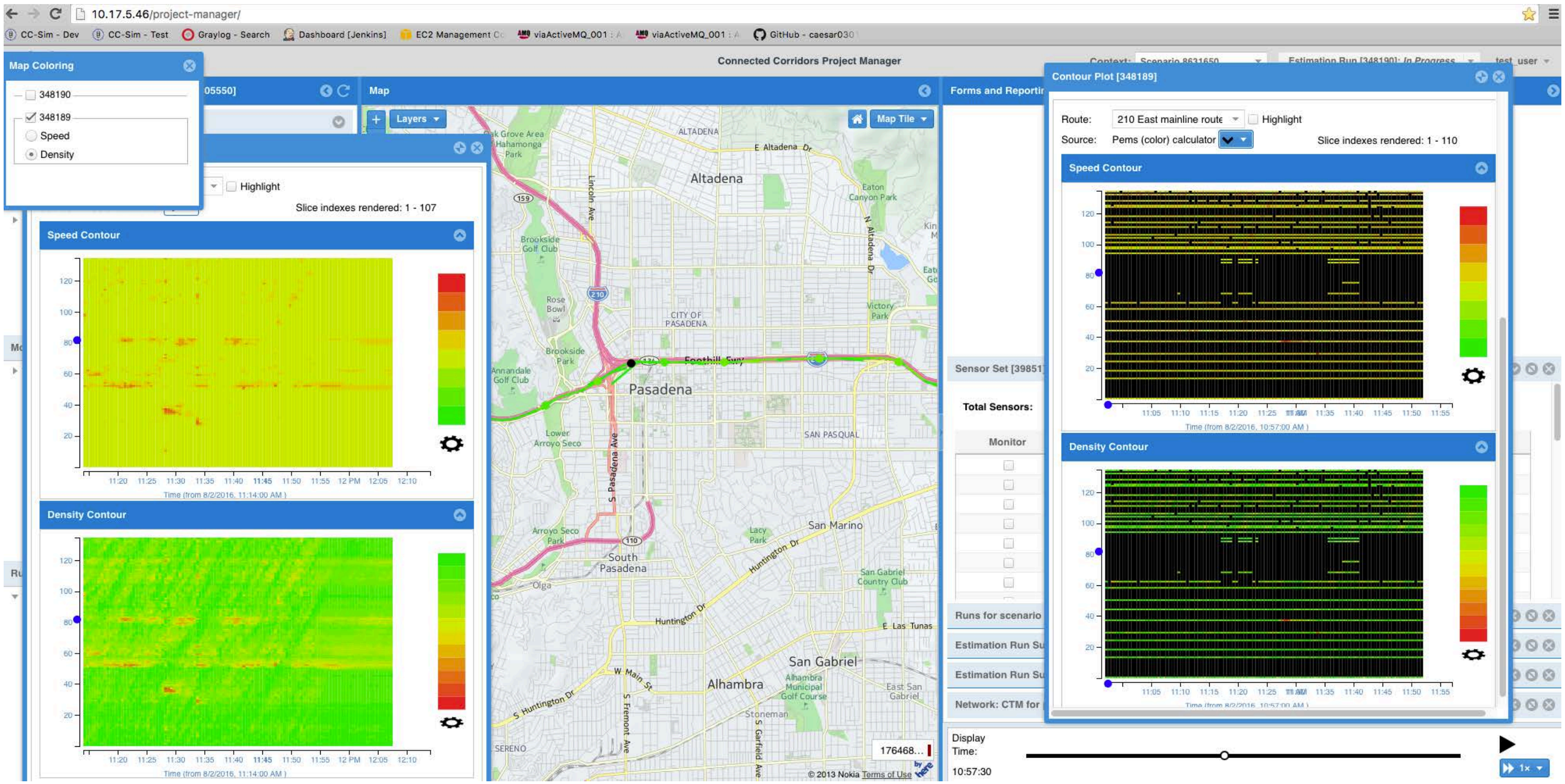
- **Estimation process**



Calibration of Freeway Estimator

- **Calibration for estimation is much easier than calibration for prediction**
- **Two key parameters**
  - Data noise variance
  - Assimilation “process noise” variance
- **Leverage data quality efforts**
  - Fundamental diagrams, turning movements, and boundary flows measured directly from data
  - Good data → good estimation results
  - Estimation fills in the blanks, so filter aggressively to remove suspect data

Estimation Running in the Cloud



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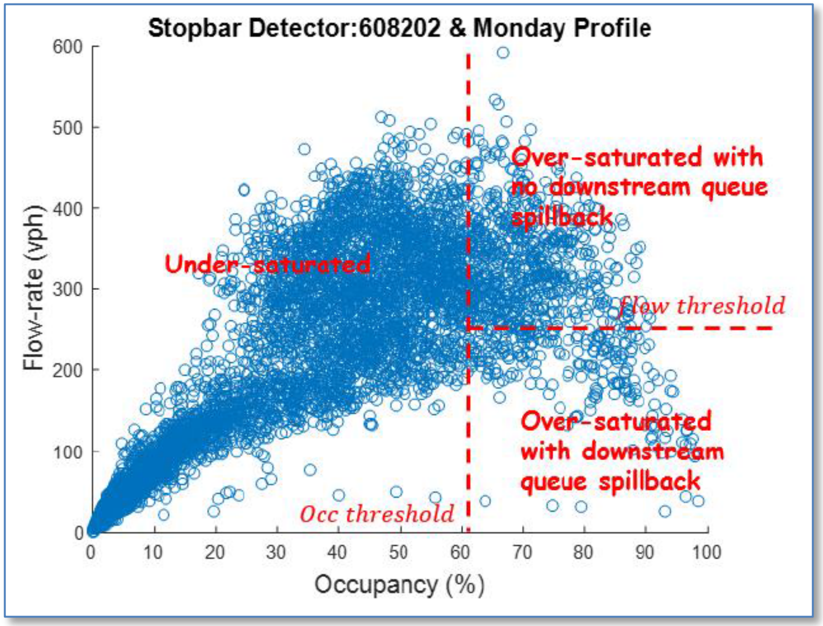
Arterial Estimation Approach

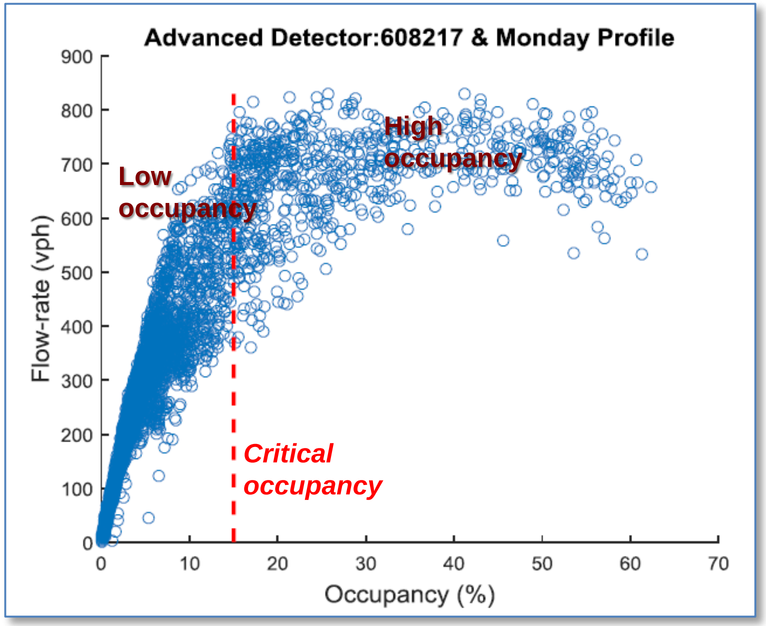
Arterial Traffic Estimation

- **Goal**
  - Estimation of traffic conditions on arterial segments at a given time based on observed data
- **Input**
  - Intersection geometry
  - Signal timing plans
  - Historical approach flows and turning counts
  - Real-time sensor counts and occupancies from advance and stop line detectors
- **Output of current process**
  - Average queue lengths for each turning movement at individual intersections

Classification of Detectors

- **Different thresholds to classify traffic conditions for different types of detectors**
  - Two thresholds for stop line detectors: detector occupancy and flow
  - One threshold for advanced detectors: critical detector occupancy

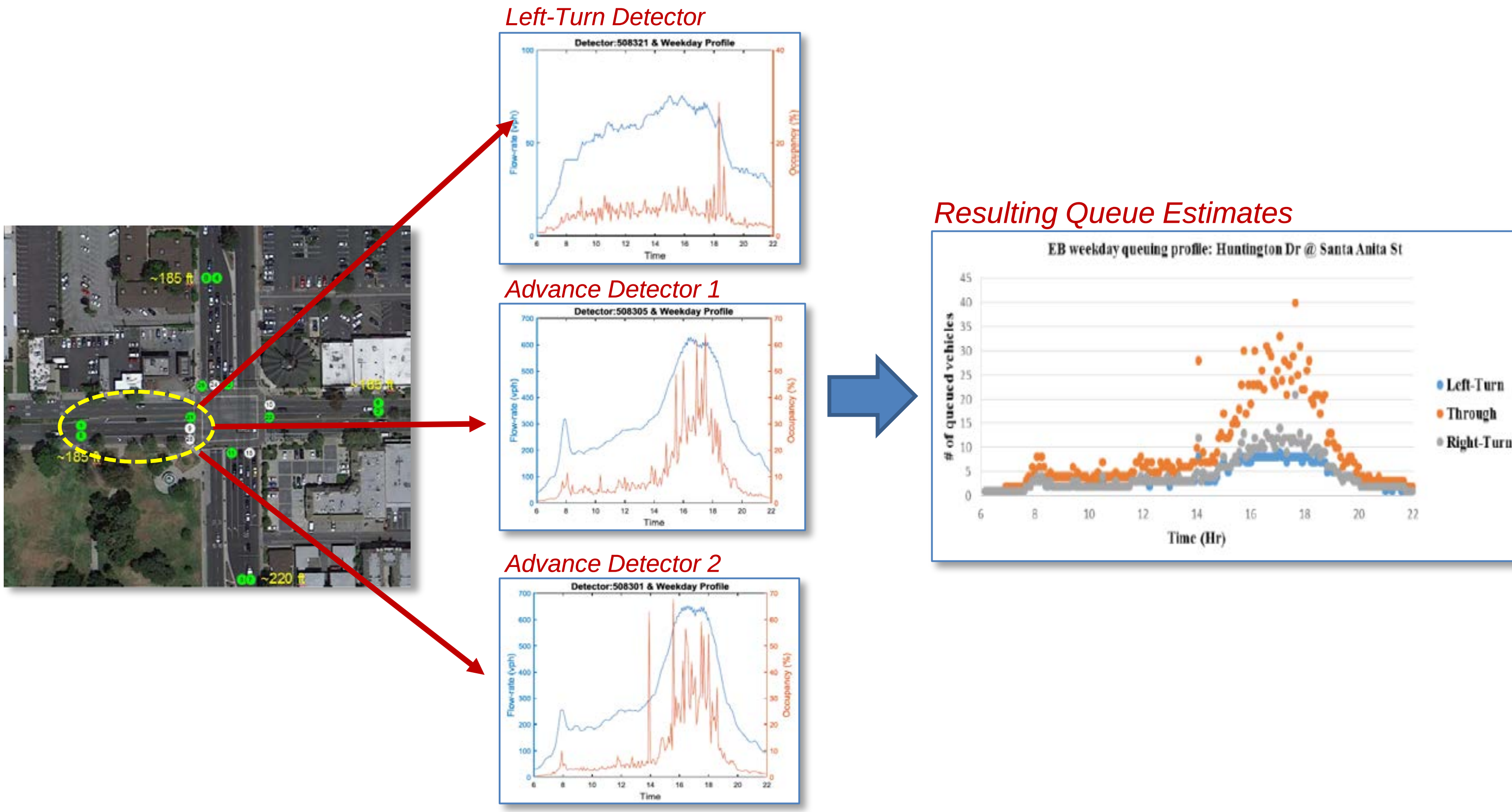




Caltrans Metro ARCADIA MONROVIA Duarte SGVCOG Foothill Transit CALIFORNIA PATH

Queue Estimation

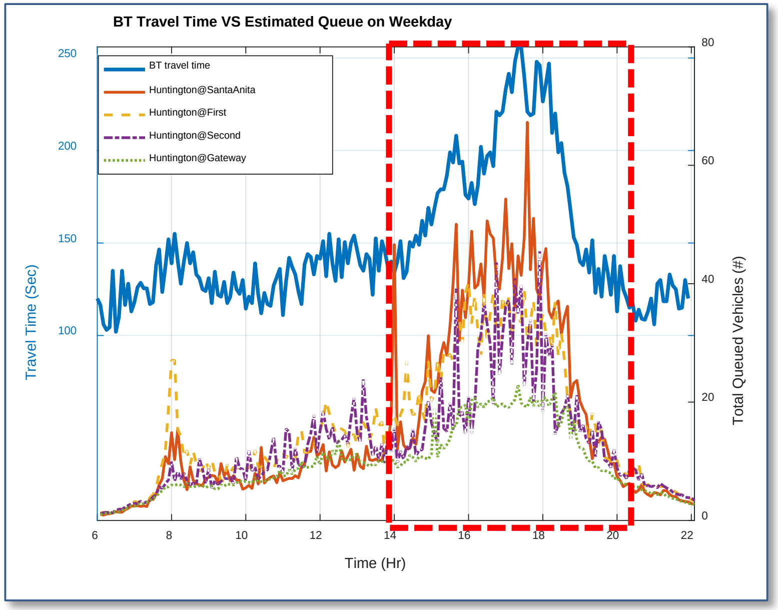
- Example: estimated queues for left-turn, through, and right-turn movements



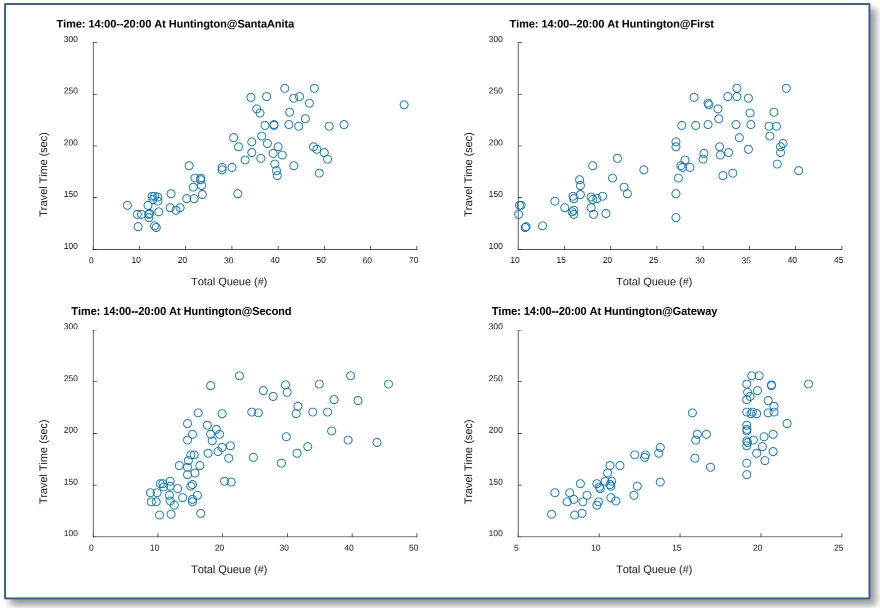
Arterial Traffic Estimation

- Estimation results consistent with Bluetooth travel times

Observed Bluetooth Travel Times vs Estimated Queues



Relationship between Observed Travel Times and Estimated Queues



Calibration of Arterial Estimator

- **Simple arterial model with nothing to tune**
- **Thresholds are calculated directly from data**
  - Two thresholds for stop line detectors: **detector occupancy** and **flow**
  - One threshold for advanced detectors: **critical detector occupancy**
- **Leverage data quality efforts**
  - Good data → good estimation results
  - Filter aggressively to remove suspect data

Input Data Quality - Freeway

Why is data quality so important?

- **Importance of high-quality data—including its timeliness, accuracy, and coverage—cannot be overstated**

Lifeblood of traffic analysis and management

- **Quality of work depends directly on quality of data**
  - Missing data → reduced situational awareness
    - Unable to locate routes with available capacity
  - Bad data → bad decisions
    - → Bad management and worse traffic
    - → Increased risk to pilot deployment

Data Quality Considerations

- **Basic detector health**
  - Do we know and agree where the sensors are?
  - Are the sensors labeled and configured correctly?
    - No sensors on the wrong side of the freeway
    - No HOV sensors mistaken for ML sensors, etc.
  - Do the sensors capture a full cross section of traffic flow?
  - Are the sensors turned on, and communicating data regularly?
- **Data Accuracy**
  - Is the data provided by a detector trustworthy?
  - When we compare traffic flowing into and out of each section of freeway, do the numbers make sense (flow balance)?
  - Are data consistent with traffic engineering expectations?

Assessing Freeway Detector Health

- Weekly freeway detector health status report based on PeMS data

Weekly Average Data	Eastbound I-210 PM 25 to PM 43.25							
Quality	CD	CH	Fwy-Fwy	HOV	Mainline	Off Ramp	On Ramp	Total
May 1-7	n.a.	n.a.	100.0%	69.4%	78.4%	73.3%	86.3%	77.8%
May 8-14	n.a.	n.a.	100.0%	81.6%	87.9%	73.3%	82.1%	85.0%
May 15-21	n.a.	n.a.	100.0%	83.3%	87.4%	72.4%	83.9%	84.9%
May 22-28	n.a.	n.a.	100.0%	74.7%	80.6%	73.3%	89.9%	80.2%
May 29 - Jun 04	n.a.	n.a.	100.0%	66.1%	70.7%	68.6%	81.0%	71.5%
Jun 05-11	n.a.	n.a.	100.0%	78.0%	82.4%	70.5%	82.1%	80.7%
Jun 12-18	n.a.	n.a.	100.0%	85.3%	90.2%	73.3%	89.3%	87.5%
Jun 19-25	n.a.	n.a.	90.5%	80.0%	87.2%	72.9%	88.1%	84.5%
Jun 26-Jul2	n.a.	n.a.	66.7%	72.2%	81.5%	73.3%	91.7%	79.8%
Jul3-9	n.a.	n.a.	66.7%	70.2%	79.2%	70.0%	89.3%	77.4%
Jul10-16	n.a.	n.a.	64.3%	78.0%	87.1%	68.6%	92.3%	83.4%
Jul17-23	n.a.	n.a.	47.6%	81.2%	87.7%	71.4%	93.5%	84.4%
Jul24-30	n.a.	n.a.	61.9%	75.1%	80.2%	60.0%	74.4%	76.0%
Jul31-Aug06	n.a.	n.a.	33.3%	77.6%	82.2%	64.3%	82.7%	78.2%
Aug07-Aug13	n.a.	n.a.	33.3%	82.9%	87.7%	70.0%	92.3%	84.0%
Aug14-Aug20	n.a.	n.a.	33.3%	78.4%	85.8%	71.9%	87.5%	81.9%
Aug21-Aug27	n.a.	n.a.	33.3%	86.5%	90.5%	78.6%	92.9%	87.3%
Aug28-Sept3	n.a.	n.a.	33.3%	86.5%	91.1%	78.1%	92.3%	87.5%
Sept4-Sept10	n.a.	n.a.	33.3%	84.5%	90.5%	73.8%	91.1%	86.2%
Sept11-Sept18	n.a.	n.a.	33.3%	86.5%	91.4%	78.1%	89.9%	87.5%
Sept18-Sept25	n.a.	n.a.	33.3%	87.8%	92.7%	81.0%	91.7%	88.9%
Sept25-Oct2	n.a.	n.a.	33.3%	84.9%	90.3%	74.3%	91.1%	86.2%
Loops in Category	0	0	6	35	148	30	24	243

Assessing Freeway Detector Health

- **Daily check of detector flow data for consistency**
- **Diagnostics to assist with identification of**
  - Missing data
  - Problematic sensors,
  - Follow up fix requests

ID	Fwy	Name	Type	1-Jun	2-Jun	3-Jun	4-Jun	5-Jun	6-Jun	7-Jun	8-Jun	9-Jun	10-Jun	11-Jun	12-Jun	13-Jun
716578	I210-W	LINCOLN 1	On Ramp	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data
763911	I210-W	LINCOLN 2	Off Ramp	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok
770568	I210-W	HAMMOND S	Mainline	Others	Others	Others	Others	Others	Others	Others	Others	Others	Others	Others	Dir	Others
717624	I210-W	MOUNTAIN 1	Mainline	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data
717623	I210-W	MOUNTAIN 1	Off Ramp	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok
716579	I210-W	MOUNTAIN 1	On Ramp	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok
770579	I210-W	WINONA WA	Mainline	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir
770165	I210-W	EB 134 TO WI	On Ramp	Others	Others	Others	Others	Others	Others	Others	Others	Others	Others	Others	Others	Others
770157	I210-W	EB 134 TO WI	Mainline	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data
716582	I210-W	WALNUT	On Ramp	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data
717627	I210-W	WALNUT	Mainline	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data
769300	I210-W	WB 210 TO O	Off Ramp	Others	Others	Others	Others	Others	Others	Others	Others	Others	Others	Others	Others	Others
717630	I210-W	FAIR OAKS 1	Mainline	Both	HOV	HOV	Dir	HOV	HOV	HOV	HOV	Both	Ok	Ok	Dir	HOV
716583	I210-W	FAIR OAKS 1	On Ramp	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok
717632	I210-W	FAIR OAKS 1	HOV	Both	Both	HOV	Ok	HOV	HOV	HOV	HOV	HOV	Ok	Ok	Ok	HOV
773132	I210-W	FAIR OAKS O	Off Ramp	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok
764137	I210-W	MARENGO	Mainline	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok
764135	I210-W	MARENGO	HOV	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok
764349	I210-W	MARENGO	Off Ramp	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok
716586	I210-W	LAKE 1	On Ramp	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok
717634	I210-W	LAKE 1	Mainline	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok
761318	I210-W	LAKE 1	HOV	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok

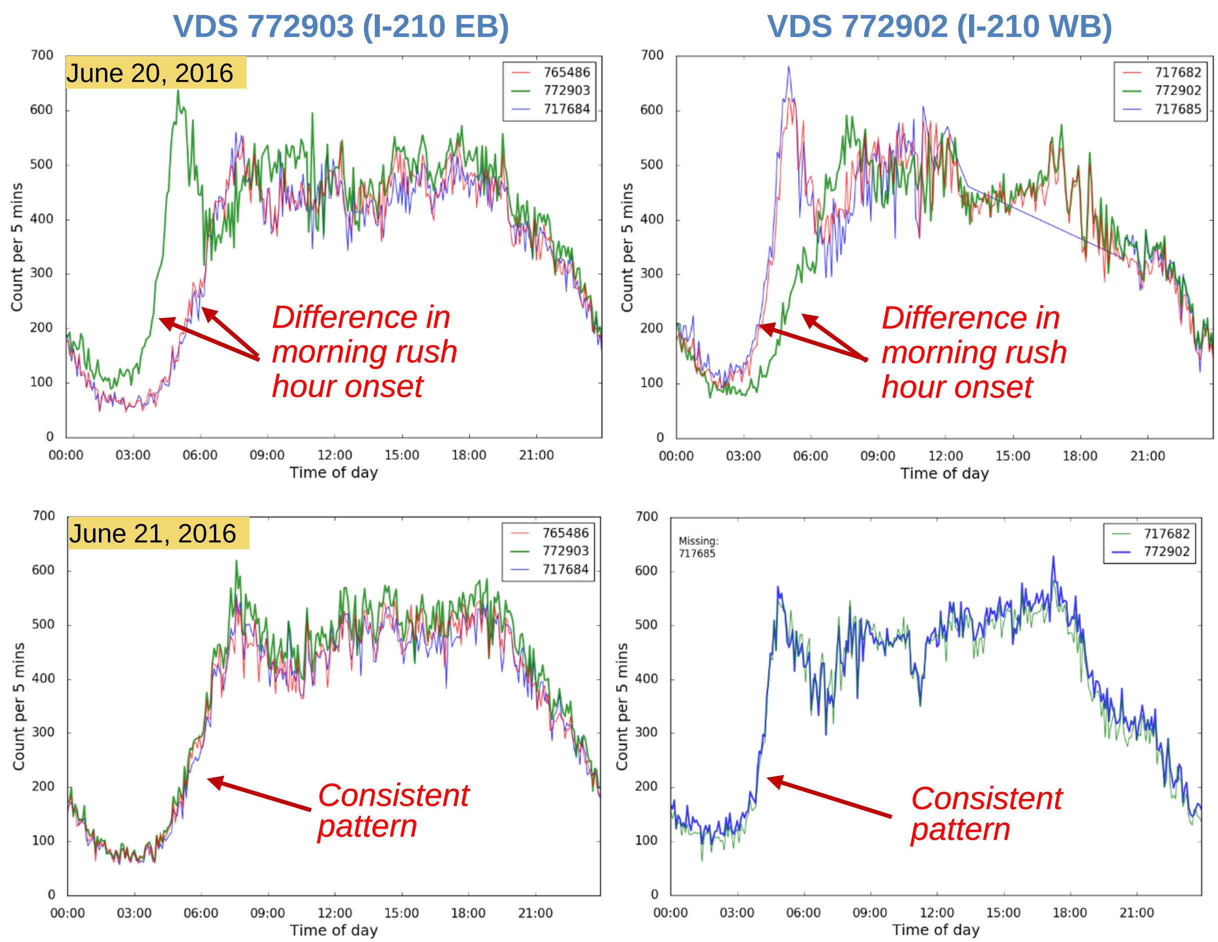
Fixing Freeway Detectors

- **Example: Fix requests for detectors assigned to wrong side of freeway or wrong lane**

Fwy	City	Abs PM	ID	Name	Type	Issue to be addressed
I210-E	Azusa	40.189	772905	PASADENA AVE	HOV	Wrong side of fwy
I210-W	Azusa	40.189	772904	PASADENA AVE	HOV	
I210-E	Azusa	40.189	772903	PASADENA AVE	Mainline	Wrong side of fwy
I210-W	Azusa	40.189	772902	PASADENA AVE	Mainline	
I605-N	Irwindale	26.552	773795	ARROW HIGHWAY	Mainline	Wrong side of fwy
I605-S	Irwindale	26.552	773796	ARROW HIGHWAY	Mainline	
SR134-W	Los Angeles	11.623	774032	COLORADO	Mainline	GP/HOV swap
SR134-W	Los Angeles	11.623	774034	COLORADO	HOV	
I210-E	Azusa	39.929	765477	AZUSA 1	Mainline	GP/HOV swap
I210-E	Azusa	39.929	770407	AZUSA 1	HOV	
I210-W	Duarte	35.409	761371	BUENA VISTA	HOV	GP/HOV swap
I210-W	Duarte	35.409	761374	BUENA VISTA	Mainline	
I210-W	Arcadia	30.999	717665	BALDWIN 2	HOV	GP/HOV swap
I210-W	Arcadia	30.999	717664	BALDWIN 2	Mainline	
I210-W	Arcadia	30.139	717661	MICHILLINDA	Mainline	GP/HOV swap
I210-W	Arcadia	30.139	761327	MICHILLINDA	HOV	
I210-W	Pasadena	28.27	717645	SAN GABRIEL	HOV	Ramp configured as HOV

Fixing Freeway Detectors – Example 1

- Detectors assigned to wrong side of freeway

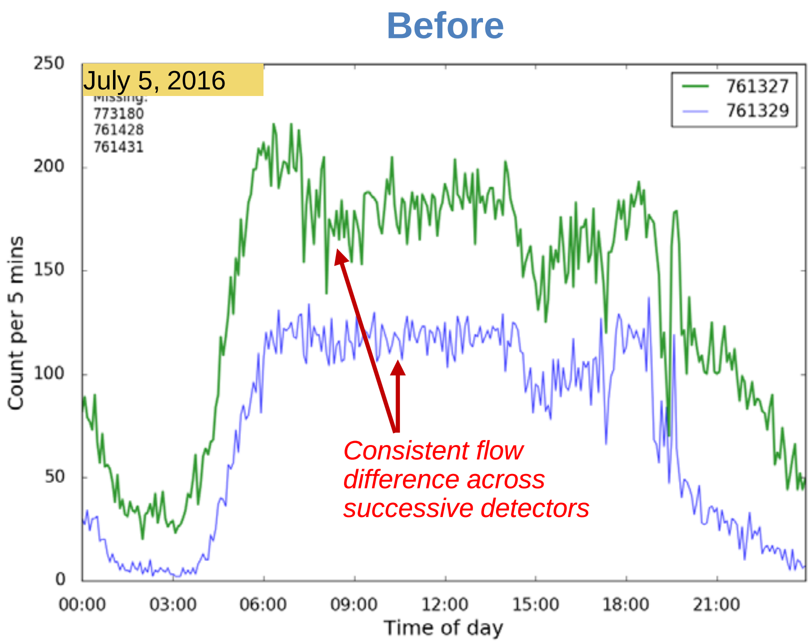


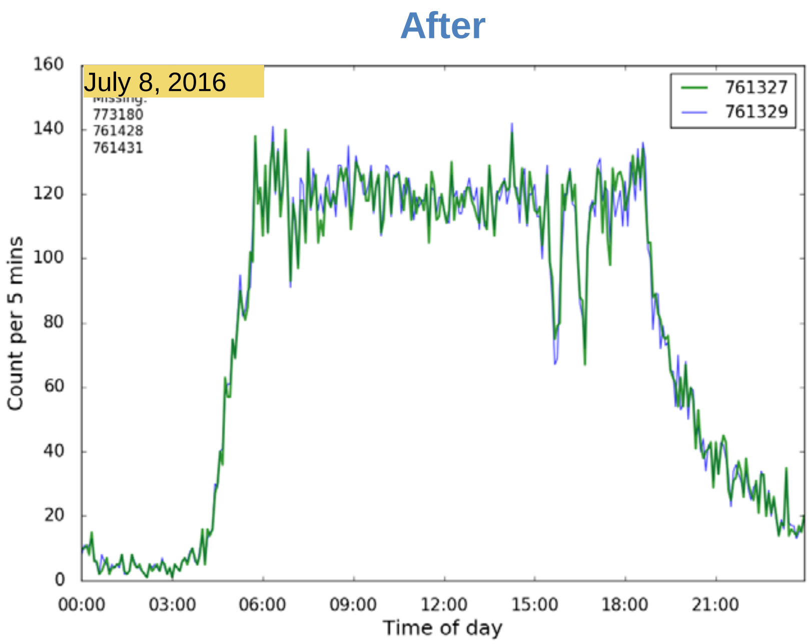
Consistent Eastbound Pattern

Consistent Westbound Pattern

Fixing Freeway Detectors – Example 2

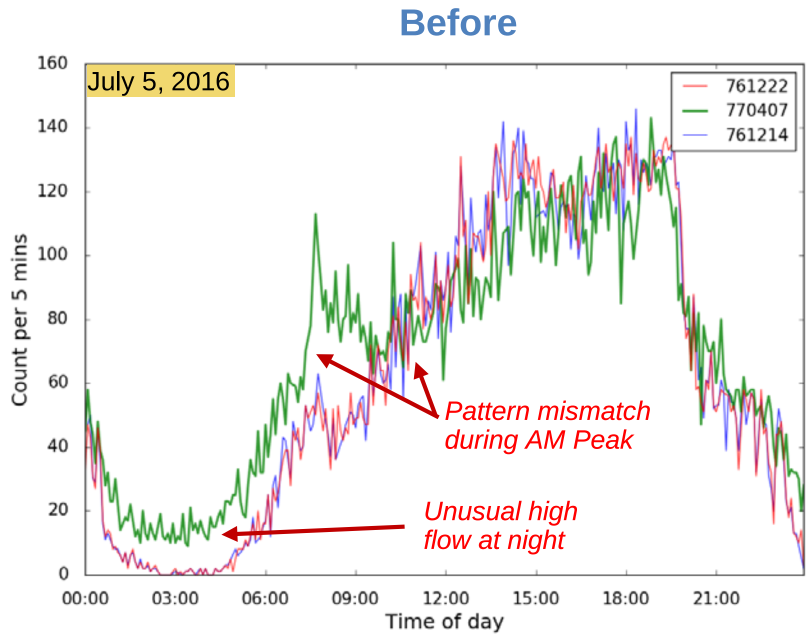
- **I-210 WB HOV lane detector at Michillinda: Incorrect HOV/general purpose lane assignments**

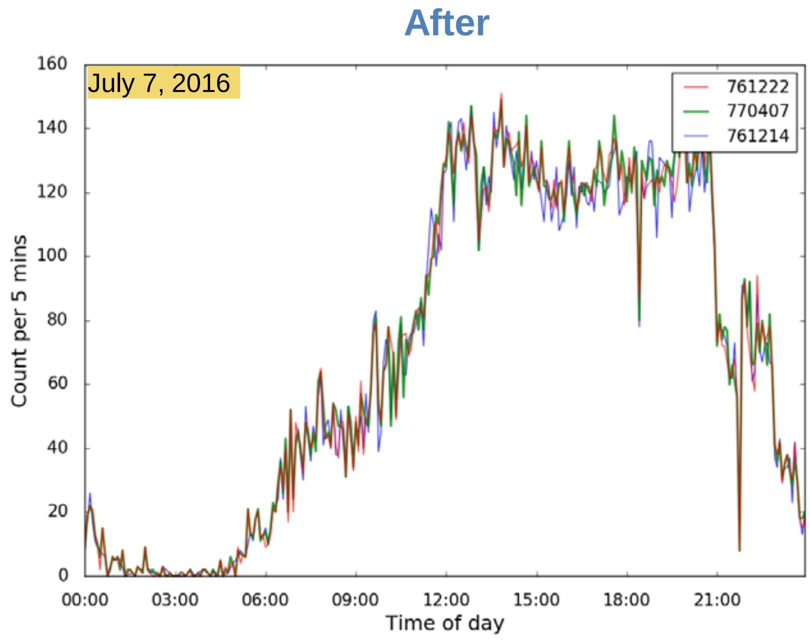




Fixing Freeway Detectors – Example 3

- **I-210 EB HOV lane detector at Azusa 1: Incorrect HOV/general purpose lane assignments**





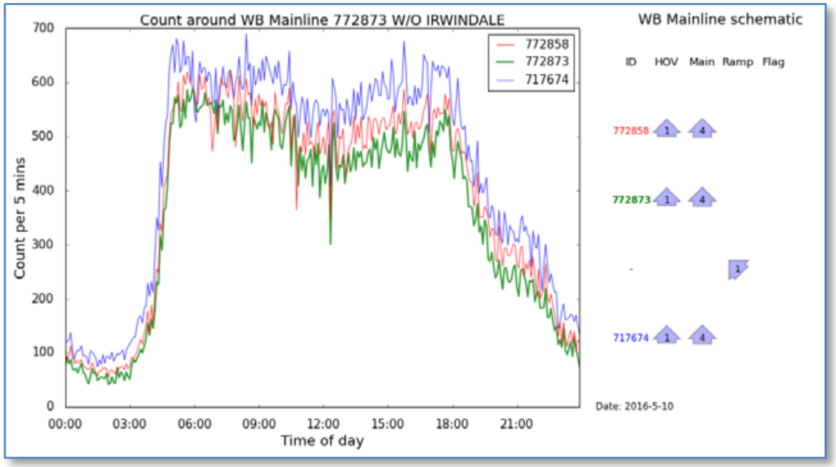
Fixing Freeway Detectors – Example 4

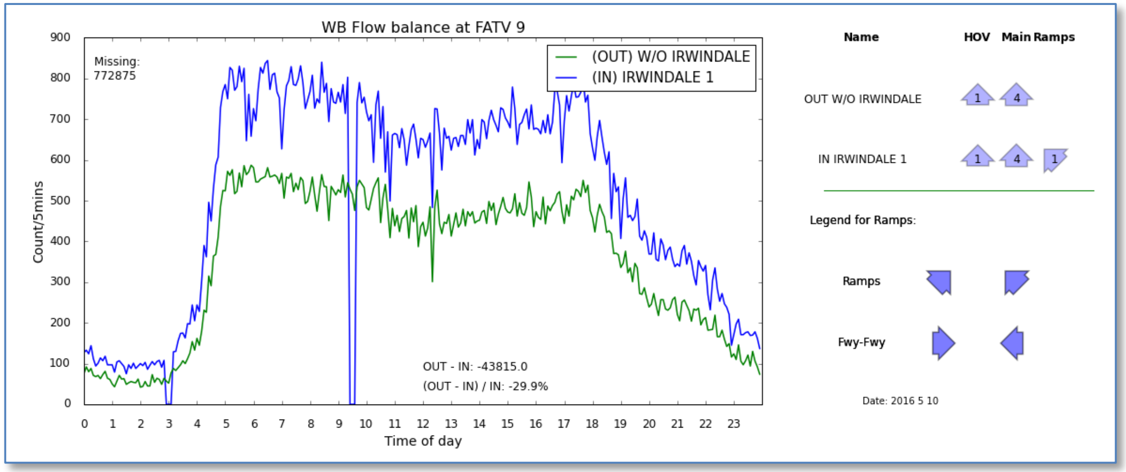
- **I-210 WB west of Irwindale: Flow undercounting**

  30% observed balance flow different between successive stations

  balance error is not possible with just a missing HOV lane alone (772875).

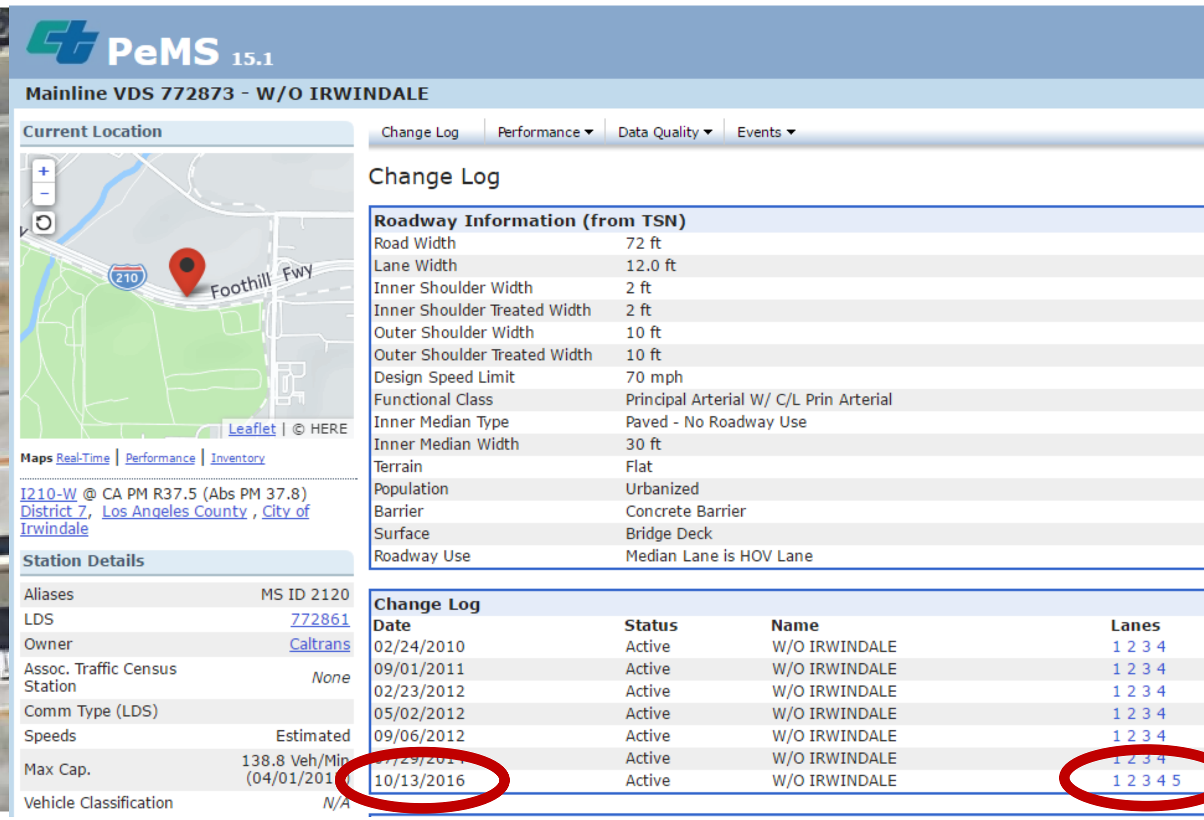
  Likely due to missing lane data





Fixing Freeway Detectors – Example 4

- VDS 772873 on I-210 WB west of Irwindale



Station Details

Aliases	MS ID 2120
LDS	772861
Owner	Caltrans
Assoc. Traffic Census Station	None
Comm Type (LDS)	
Speeds	Estimated
Max Cap.	138.8 Veh/Min (04/01/201
Vehicle Classification	N/A

Change Log

Roadway Information (from TSN)	
Road Width	72 ft
Lane Width	12.0 ft
Inner Shoulder Width	2 ft
Inner Shoulder Treated Width	2 ft
Outer Shoulder Width	10 ft
Outer Shoulder Treated Width	10 ft
Design Speed Limit	70 mph
Functional Class	Principal Arterial W/ C/L Prin Arterial
Inner Median Type	Paved - No Roadway Use
Inner Median Width	30 ft
Terrain	Flat
Population	Urbanized
Barrier	Concrete Barrier
Surface	Bridge Deck
Roadway Use	Median Lane is HOV Lane

Change Log

Date	Status	Name	Lanes
02/24/2010	Active	W/O IRWINDALE	1 2 3 4
09/01/2011	Active	W/O IRWINDALE	1 2 3 4
02/23/2012	Active	W/O IRWINDALE	1 2 3 4
05/02/2012	Active	W/O IRWINDALE	1 2 3 4
09/06/2012	Active	W/O IRWINDALE	1 2 3 4
[illegible]	Active	W/O IRWINDALE	1 2 3 4
10/13/2016	Active	W/O IRWINDALE	1 2 3 4 5

Fixing Freeway Detectors – Example 5

- **Mismatch in number of lanes covered**

Item	Fwy	VDS ID	Name	Type	Lanes in PeMS	Lanes in Google Streetview	Comments	Findings by Caltrans
1	I210-W	770568	HAMMOND ST.	Mainline	4	5	Lane count mismatch	Outside of Corridor
2	I210-W	717107	SANTA ANITA NB	On Ramp	1	2	Lane count mismatch	1 lane 1 loop: Non-issue (8/11/16) The 2 loops are Q loops, not On loops. Location of On loop identified in photo provided (9/6/16)
3	I210-W	773194	E OF SECOND	Mainline	4	5	Lane count mismatch	Requested ML5 to be added to ATMS (8/5/16)
4	I210-W	761350	MYRTLE AV	Off Ramp	2	1	Lane count mismatch	2 loops to cover 1 wide lane Requested FR2 to be removed from ATMS (8/11/16)
5	I210-W	769702	HIGHLAND	Mainline	4	5	Lane count mismatch	4 lanes 4 loops: Non-issue (8/11/16) Location identified in photo provided (9/6/16)
6	I210-W	773206	SB 605 FROM WB 210	Fwy-Fwy	2	3	Lane count mismatch	2 lanes 2 loops: Non-issue (8/11/16) The 3rd lane is SB 605 from Mount Olive (8/19/16) Location identified in photo provided (9/6/16)
7	I210-W	772858	SAN GABRIEL RIVER	Mainline	4	5	Tadeo is fixing	Requested ML5 to be added to ATMS (8/5/16)
8	I210-W	772873	W/O IRWINDALE	Mainline	4	5	Lane count mismatch	Requested ML5 to be added to ATMS (8/11/16)
9	I210-W	717678	AZUSA 1	Mainline	4	5	Lane count mismatch	Requested ML5 to be added to ATMS (8/23/16)
10	I210-E	761177	BUENA VISTA	Mainline	4	5	Lane count mismatch	Requested ML5 to be added to ATMS (8/23/16)
11	I210-E	769774	NB 605 TO EB 210 CON	On Ramp	1	2	Mismatch in PeMS only	PeMS issue (8/10/16)
12	I210-E	772857	SAN GABRIEL RIVER	Mainline	4	5	Tadeo is fixing	Requested ML5 to be added to ATMS (8/5/16)
13	I210-E	774990	IRWINDALE 1	Off Ramp	1	2	Lane count mismatch	1 loop functioning; 1 loop missing DLC (8/11/16)
14	I210-E	718469	CITRUS 2	Mainline	4	5	Lane count mismatch	merging with an on-ramp. Will need to replace ML4 with a wider loop (8/18/16)
15	SR134-W	769301	EB 210 TO WB 134 #2	Fwy-Fwy	1	2	Lane count mismatch	Outside of Corridor
16	SR134-E	717605	ORANGE GROVE	Off Ramp	1	2	Lane count mismatch	Outside of Corridor

Fixing Freeway Detectors – Example 6

- **Sensors not returning data**

Item	Fwy	VDS ID	Name	Type	MS ID	Comments	Findings by Caltrans
17	I605-S	766926	605 SB TO ARROW WB	Off Ramp	4428	Appear permanently broken	Bad loop (8/17/16)
18	I605-S	766925	605 SB TO ARROW EB	Off Ramp	4428	Appear permanently broken	Bad loop (8/17/16)
19	I605-S	773798	ROUTE 605/ ROUTE 210	Mainline	2443	Appear permanently broken	Solar panel issue (8/17/16)
20	I605-S	774260	MT OLIVE TO SB 605	Coll/Dist	4430	Appear permanently broken	Bad loop (8/17/16)
21	I605-N	773807	ROUTE 605/ ROUTE 210	Mainline	2443	Appear permanently broken	Solar panel issue (8/17/16)
22	I210-W	761322	HILL	HOV	4308	Appear permanently broken	
23	I210-W	717645	SAN GABRIEL	HOV	4306	Appear permanently broken	Bad Loop (9/30/16)
24	I210-W	717656	ROSEMEAD 2	Off Ramp	4569	Appear permanently broken	Bad Loop (9/30/16)
25	I210-W	717662	BALDWIN SB	Off Ramp	4303	Appear permanently broken	Misconfigured (9/30/16)
26	I210-W	717665	BALDWIN 2	HOV	4302	Appear permanently broken	Controller Down (9/30/16)
27	I210-W	717668	SANTA ANITA SB	Off Ramp	4301	Appear permanently broken	Misconfigured (9/30/16)
28	I210-W	764144	SANTA ANITA 2	HOV	4300	Appear permanently broken	
29	I210-W	773196	E OF SECOND	HOV	2117	Appear permanently broken	Communications Issue (9/30/16)
30	I210-W	773194	E OF SECOND	Mainline	2117	Appear permanently broken	Communications Issue (9/30/16)
31	I210-W	761350	MYRTLE AV	Off Ramp	4298	Appear permanently broken	Good-Fixed (9/30/16)
32	I210-W	772875	W/O IRWINDALE	HOV	2120	Appear permanently broken	Good-Fixed (8/12/16)
33	I210-W	761386	AZUSA 1	HOV	4290	Appear permanently broken	Conduit Damaged (9/30/16)
34	I210-W	717678	AZUSA 1	Mainline	4290	Appear permanently broken	Conduit Damaged (9/30/16)
35	I210-W	716610	AZUSA SB	On Ramp	4290	Appear permanently broken	Conduit Damaged (9/30/16)
36	I210-E	773131	FAIR OAKS OFF	Fwy-Fwy	2547	Appear permanently broken	
37	I210-E	761098	LAKE 2	HOV	4248	Appear permanently broken	
38	I210-E	769272	HILL AVE OFF	Off Ramp	2575	Appear permanently broken	Missing Cabinet, Maintenance will fix (9/30/16)
39	I210-E	716589	HILL NB	On Ramp	4249	Appear permanently broken	Fixed - Shows all Green in PeMs (9/30/16)
40	I210-E	763908	SIERRA MADRE V1	Off Ramp	2568	Appear permanently broken	SD2 change to SD3 - change form sent (9/30/16)
41	I210-E	773193	E OF SECOND	Mainline	2117	Appear permanently broken	Communications Issue (9/30/16)
42	I210-E	773195	E OF SECOND	HOV	2117	Appear permanently broken	Communications Issue (9/30/16)
43	I210-E	761128	HUNTINGTON 1	Mainline	4257	Appear permanently broken	Fixed - Shows all Green in PeMs (9/30/16)
44	I210-E	761126	HUNTINGTON 1	HOV	4257	Appear permanently broken	Fixed - Shows all Green in PeMs (9/30/16)
45	I210-E	761130	HUNTINGTON WB	Off Ramp	4257	Appear permanently broken	SD4 bit needs to be turned on (9/30/16)
46	I210-E	718205	HUNTINGTON WB	On Ramp	4257	Appear permanently broken	Fixed - Shows all Green in PeMs (9/30/16)
47	I210-E	761154	MYRTLE AV	Off Ramp	4259	Appear permanently broken	
48	I210-E	761167	MOUNTAIN	Off Ramp	4260	Appear permanently broken	OFF1 bit needs to be turned on (9/30/16)

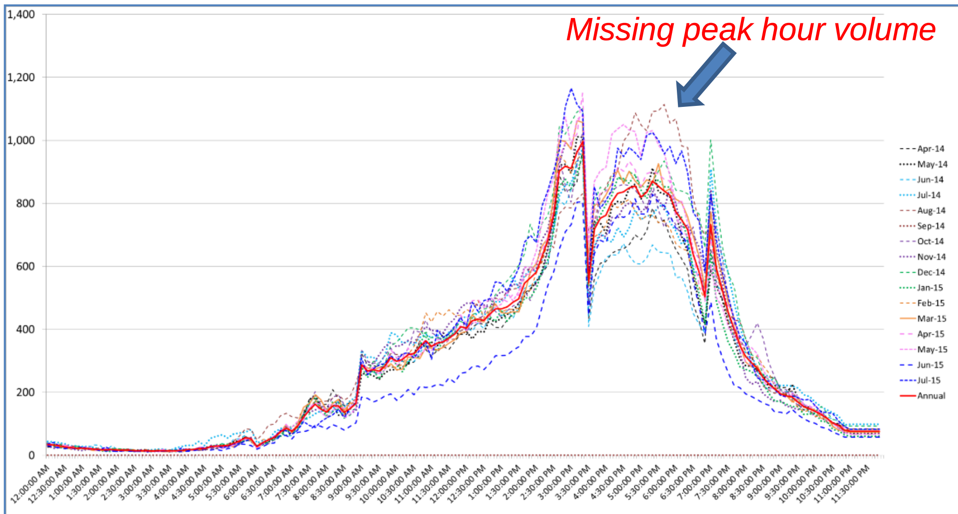
Input Data Quality - Arterial

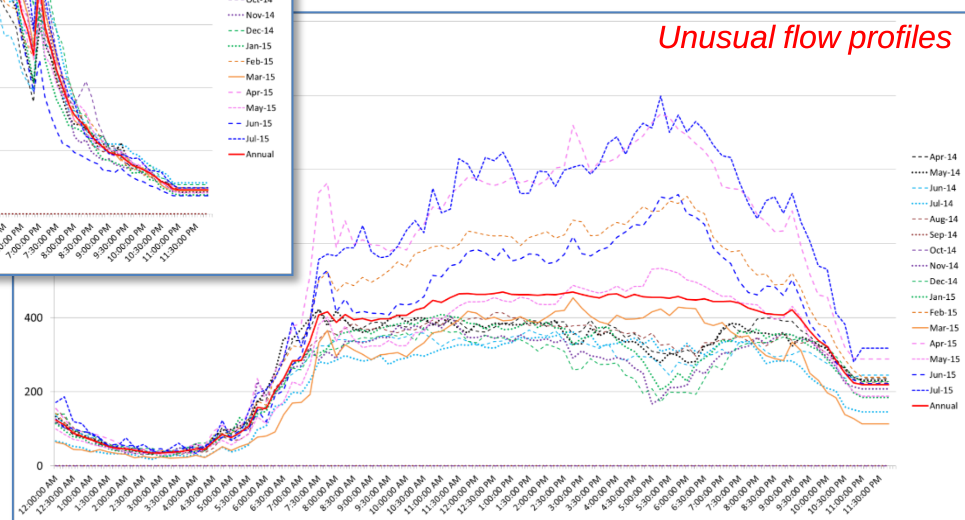
Why is data quality so important?

- **As previously indicated:**
  - Data is the lifeblood of traffic analysis and management
  - Quality of work depends directly on quality of data
- **Key considerations**
  - Detector health
  - Factors affecting data
  - Data adjustments

Assessing Detector Health

- **Detector operational problems can significantly affect data produced by arterial sensors**





Assessing Detector Health

- **Identification of suspected errors**

PeMS Freeway Data Messages

- Line Down
- Controller Down
- No Data
- Card Off
- Insufficient Data
- Constant Value
- Intermittent (Zero flow and non-zero occupancy)
- High Value
- Feed Unstable

Arterial Data Analysis Criteria

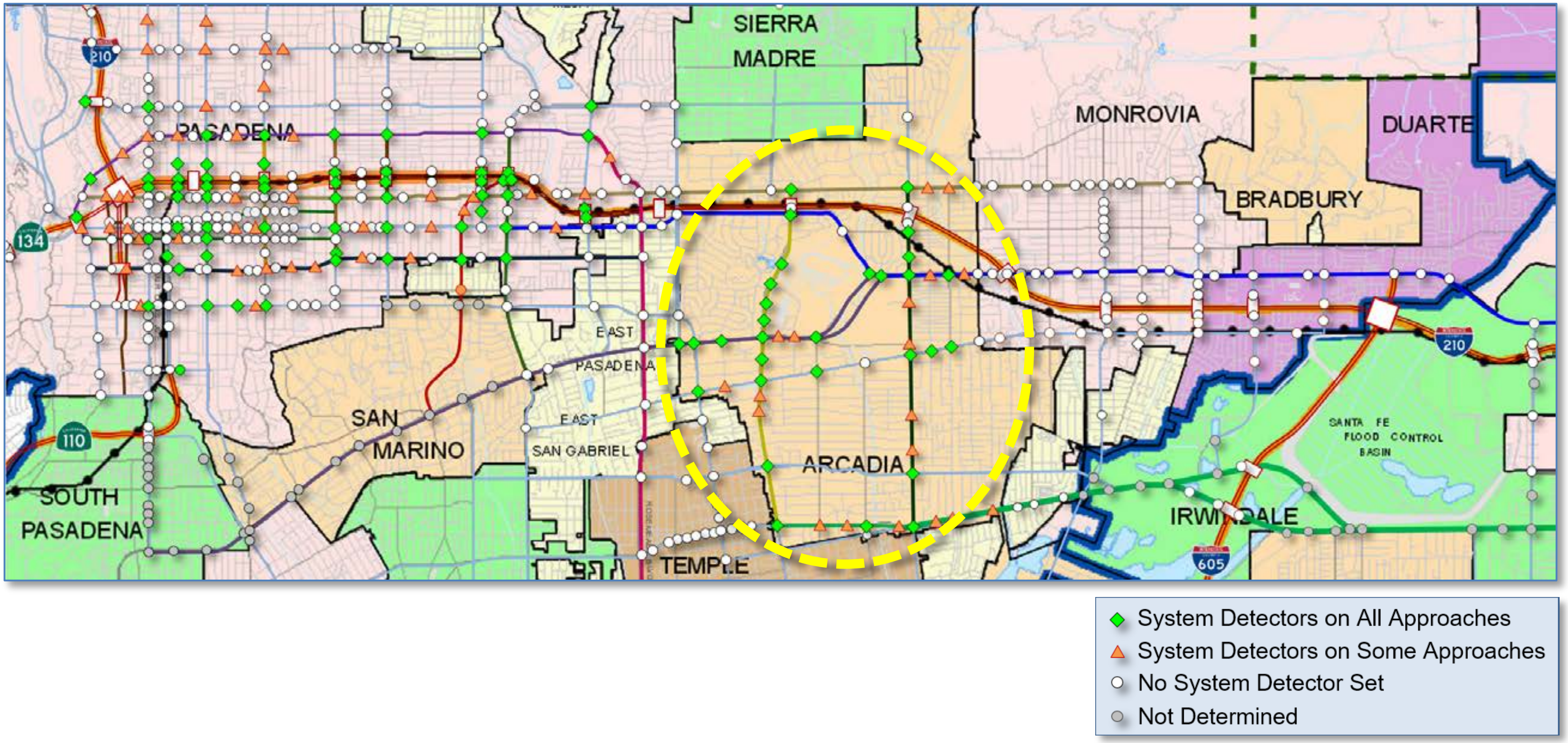
- No Data
- Missing Data
- Reporting Zero Values
- Inconsistent Data (e.g., zero occupancy and non-zero flow)

(Line Down, Controller Down, No Data, Card Off → No Data; Insufficient Data → Missing Data; Constant Value → Reporting Zero Values; Intermittent (Zero flow and non-zero occupancy) → Inconsistent Data)

- **Detector categorized as "Good" if it satisfies**
  - Missing rate<5%
  - Inconsistency rate <15% (e.g., Occ =0 and flow/speed !=0)
  - Not reporting zero values (Major issue in Arcadia)

Assessing Detector Health

- Example: System detection data from Arcadia



Assessing Detector Health

- **Example: Weekly detector health status report for Arcadia**

Intersections			System Detectors		
Total	Detour Routes		Status		Total
51	Yes	35	ON_LINE	407	434
			COMM_ERROR	23	
			COMM_ERROR/ON_LINE	4	
	No	16	ON_LINE	65	145
			COMM_ERROR	76	
			COMM_ERROR/ON_LINE	4	

Criteria for "Good" detectors
(i) Data missing rate <5%
(ii) Data inconsistency rate <15% (e.g., occupancy =0, but volume !=0)
(iii) Not reporting zero values (Currenlty a major issue in Arcadia)

Summary (between 11-September-2016 and 24-September-2016)
From the weekly report, we can find that: (i) the health rate increases significantly in the past two weeks, by about 10% at the network level; (ii) the health rate in the last week is currently the highest in the past eight months. Such a significant improvement may be related to the maintenance service conducted several weeks ago.

Weekly Data Quality (%)	Arcadia								
	Detour Routes			Not Detour Routes			All Detectors		
	Good	Bad	No Data	Good	Bad	No Data	Good	Bad	No Data
07-Feb-2016 To 13-Feb-2016	59.91	34.10	5.99	15.86	28.97	55.17	48.88	32.82	18.31
14-Feb-2016 To 20-Feb-2016	55.17	38.84	5.99	15.86	28.97	55.17	45.32	36.37	18.31
21-Feb-2016 To 27-Feb-2016	54.74	39.27	5.99	15.86	28.97	55.17	45.00	36.69	18.31
28-Feb-2016 To 05-Mar-2016	50.23	43.78	5.99	15.76	29.06	55.17	41.60	40.09	18.31
06-Mar-2016 To 12-Mar-2016	50.16	43.84	5.99	14.68	30.15	55.17	41.28	40.41	18.31
13-Mar-2016 To 19-Mar-2016	47.43	46.58	5.99	13.79	31.03	55.17	39.01	42.68	18.31
20-Mar-2016 To 26-Mar-2016	45.00	49.01	5.99	14.68	30.15	55.17	37.40	44.29	18.31
27-Mar-2016 To 02-Apr-2016	46.81	47.20	5.99	14.48	30.34	55.17	38.71	42.98	18.31
03-Apr-2016 To 09-Apr-2016	47.60	46.41	5.99	14.48	30.34	55.17	39.30	42.39	18.31
10-Apr-2016 To 16-Apr-2016	48.52	45.49	5.99	14.48	30.34	55.17	40.00	41.70	18.31
17-Apr-2016 To 23-Apr-2016	47.00	47.00	5.99	14.48	30.34	55.17	38.86	42.83	18.31
24-Apr-2016 To 30-Apr-2016	48.29	45.72	5.99	14.38	30.44	55.17	39.80	41.89	18.31
01-May-2016 To 07-May-2016	39.10	41.47	19.42	9.16	29.26	61.58	31.61	38.42	29.98
08-May-2016 To 14-May-2016	57.57	36.44	5.99	13.60	31.23	55.17	46.56	35.13	18.31
15-May-2016 To 21-May-2016	60.20	33.81	5.99	14.78	30.05	55.17	48.83	32.86	18.31
22-May-2016 To 28-May-2016	63.10	30.91	5.99	14.58	30.25	55.17	50.95	30.74	18.31
29-May-2016 To 04-Jun-2016	61.62	32.39	5.99	13.89	30.94	55.17	49.67	32.03	18.31
05-Jun-2016 To 11-Jun-2016	52.07	41.94	5.99	10.34	34.48	55.17	41.62	40.07	18.31
12-Jun-2016 To 18-Jun-2016	47.00	47.00	5.99	10.34	34.48	55.17	37.82	43.87	18.31
19-Jun-2016 To 25-Jun-2016	49.05	44.96	5.99	11.33	33.50	55.17	39.60	42.09	18.31
26-Jun-2016 To 02-Jul-2016	51.38	42.63	5.99	8.97	35.86	55.17	40.76	40.93	18.31
03-Jul-2016 To 09-Jul-2016	51.91	42.10	5.99	8.97	35.86	55.17	41.15	40.54	18.31
10-Jul-2016 To 16-Jul-2016	49.84	44.17	5.99	8.97	35.86	55.17	39.60	42.09	18.31
17-Jul-2016 To 23-Jul-2016	50.53	43.48	5.99	8.97	35.86	55.17	40.12	41.57	18.31
24-Jul-2016 To 30-Jul-2016	51.32	42.69	5.99	8.97	35.86	55.17	40.71	40.98	18.31
31-Jul-2016 To 06-Aug-2016	50.99	43.02	5.99	8.97	35.86	55.17	40.46	41.23	18.31
07-Aug-2016 To 13-Aug-2016	51.42	42.59	5.99	8.97	35.86	55.17	40.78	40.91	18.31
14-Aug-2016 To 20-Aug-2016	55.92	38.08	5.99	8.97	35.86	55.17	44.16	37.53	18.31
21-Aug-2016 To 27-Aug-2016	56.98	37.03	5.99	8.97	35.86	55.17	44.95	36.74	18.31
28-Aug-2016 To 03-Sep-2016	53.59	40.42	5.99	11.92	32.91	55.17	43.15	38.54	18.31
04-Sep-2016 To 10-Sep-2016	52.47	41.54	5.99	11.23	33.60	55.17	42.14	39.55	18.31
11-Sep-2016 To 17-Sep-2016	61.95	32.06	5.99	16.06	28.77	55.17	50.46	31.24	18.31
18-Sep-2016 To 24-Sep-2016	63.79	30.22	5.99	16.55	28.28	55.17	51.96	29.73	18.31

Assessing Detector Health

- **Example: Weekly detection health summary for Arcadia**

Intersections			System Detectors		
Total	Detour Routes		Status		Total
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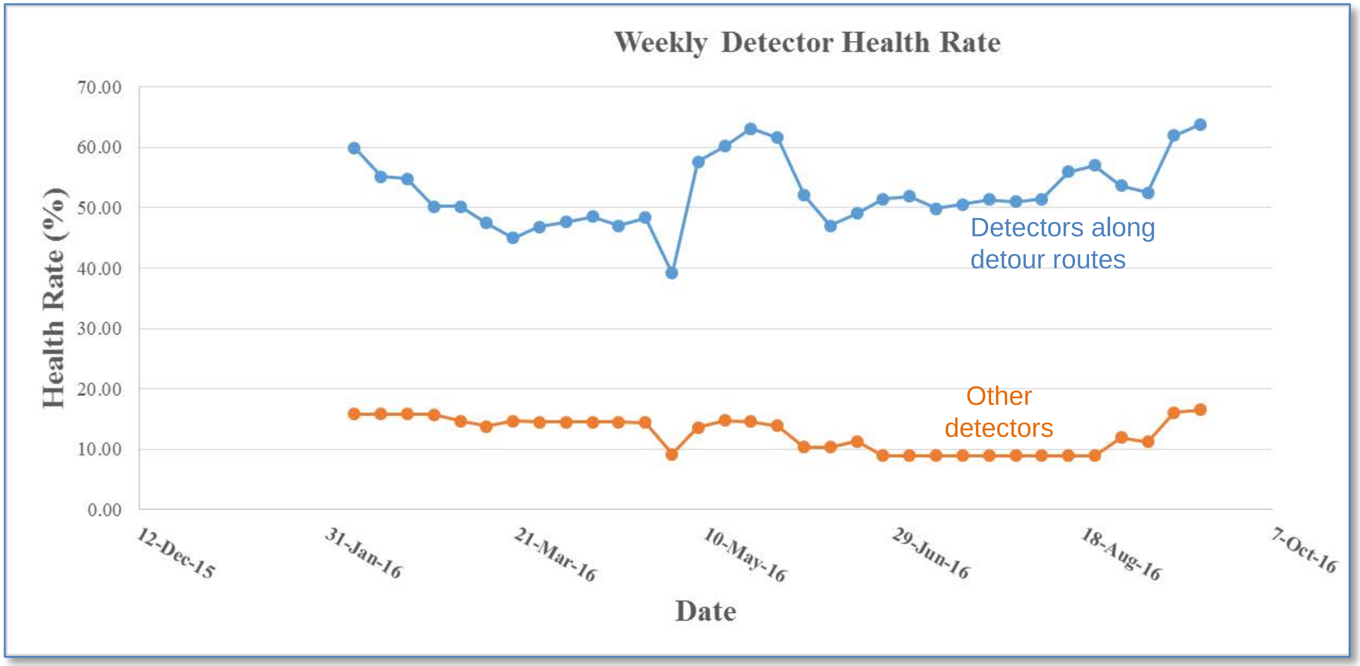
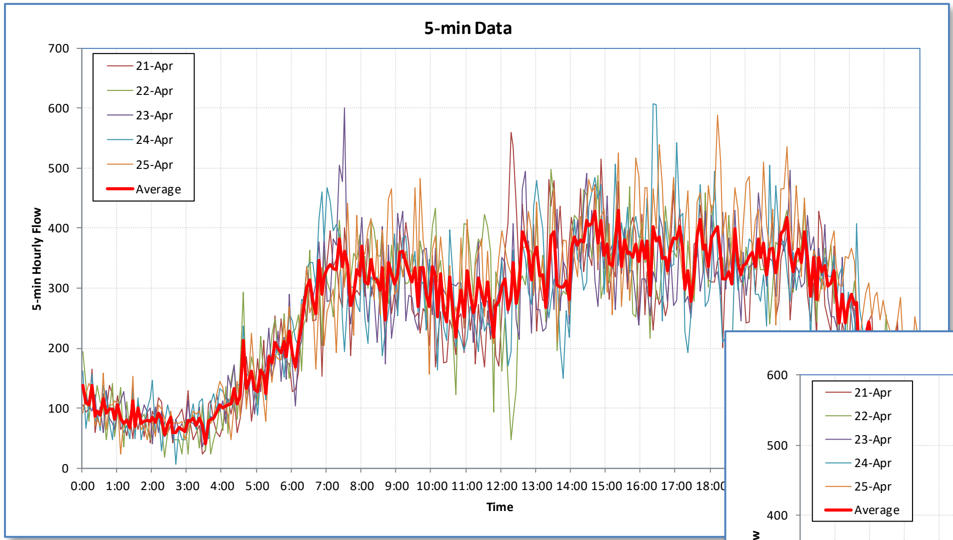
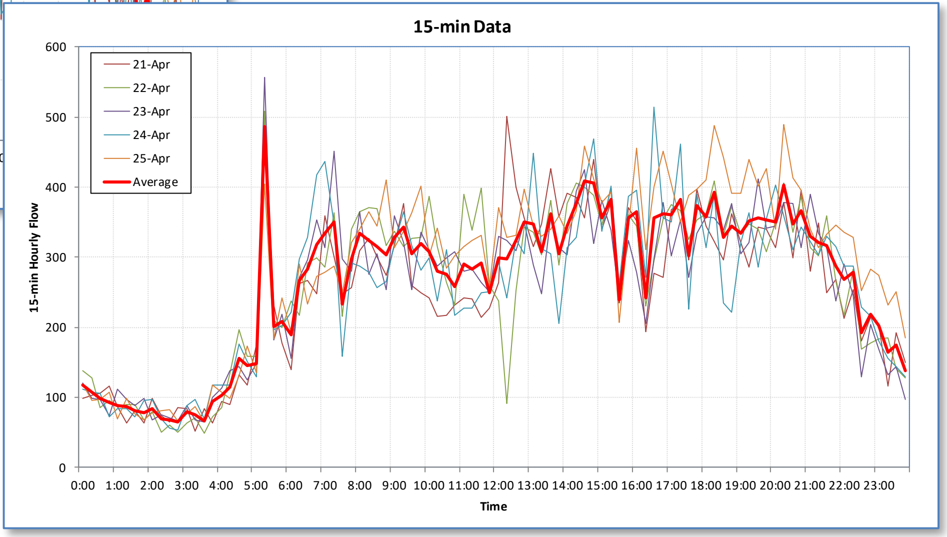


Data Factors – Data Variability

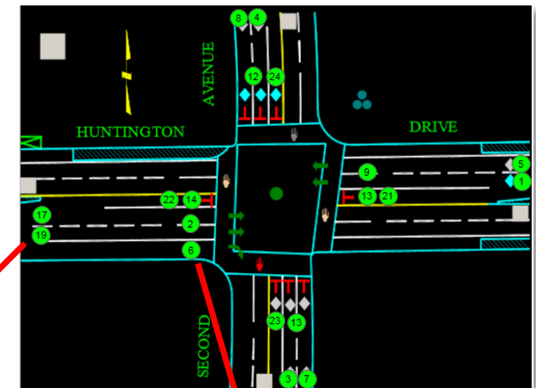
- Variability of arterial traffic flows

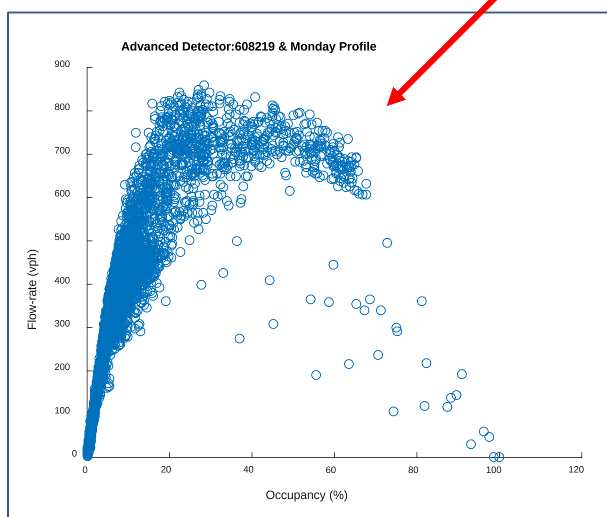




Data Factors – Flow-Occupancy Relationships

- Location of detector greatly affects the underlying flow-occupancy relationship
- Creates difficulty in identifying average relationships

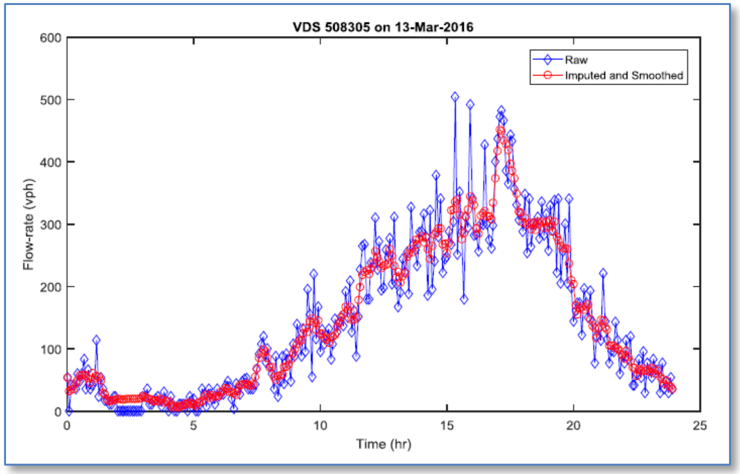


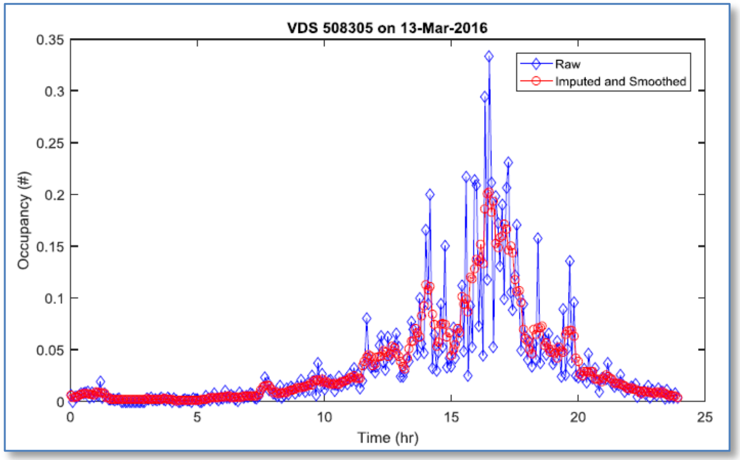


Metro

Data Adjustments – Smoothing

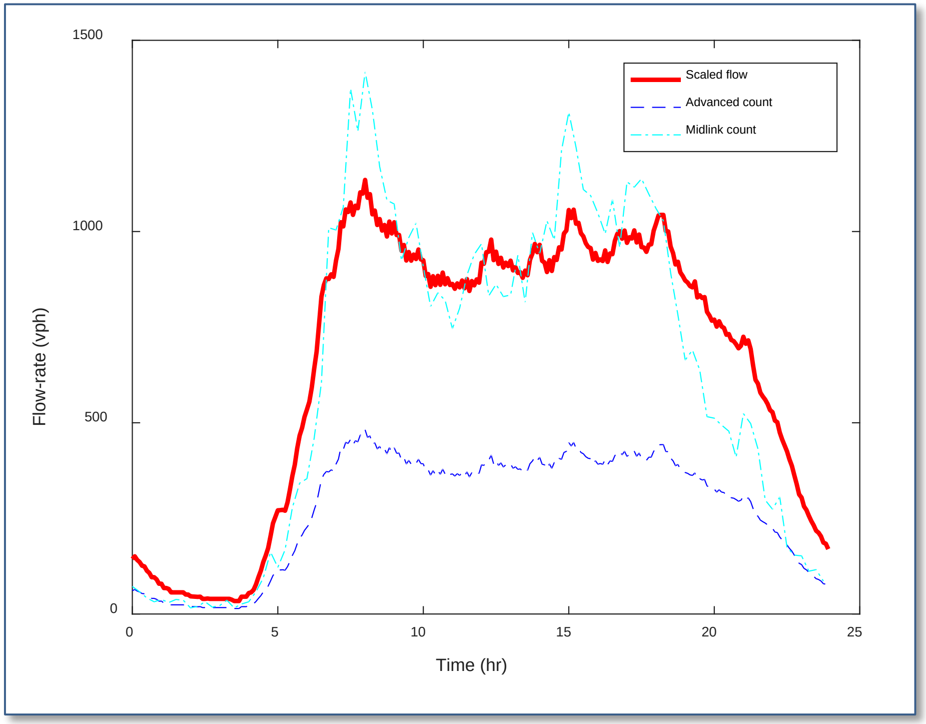
- **Issue:**
  - High degree of fluctuation, particularly when dealing with short intervals (cycle data, 5-minute data)
- **Solution:**
  - Calculate local averages with a window span of 5 intervals





Data Adjustments – Flow Rescaling

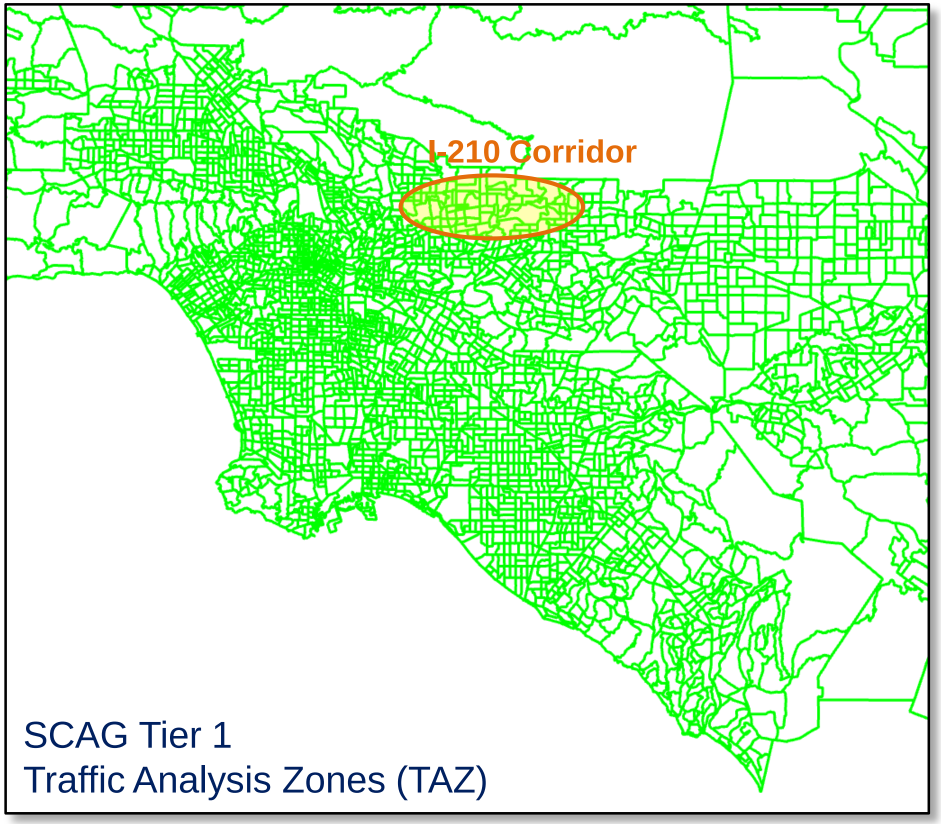
- **Issue:**
  - Consistently low flows due to incomplete detector coverage
- **Solution:**
  - Rescale observed approach flows using historical mid-link counts



Demand Modeling

What is Demand Modeling?

- Development of a table defining trips that people make within a network
  - Between specific zones
  - By time of day
  - By mode
  - By purpose
- Often related to demand model maintained by regional planning agencies



Demand Modeling Approaches

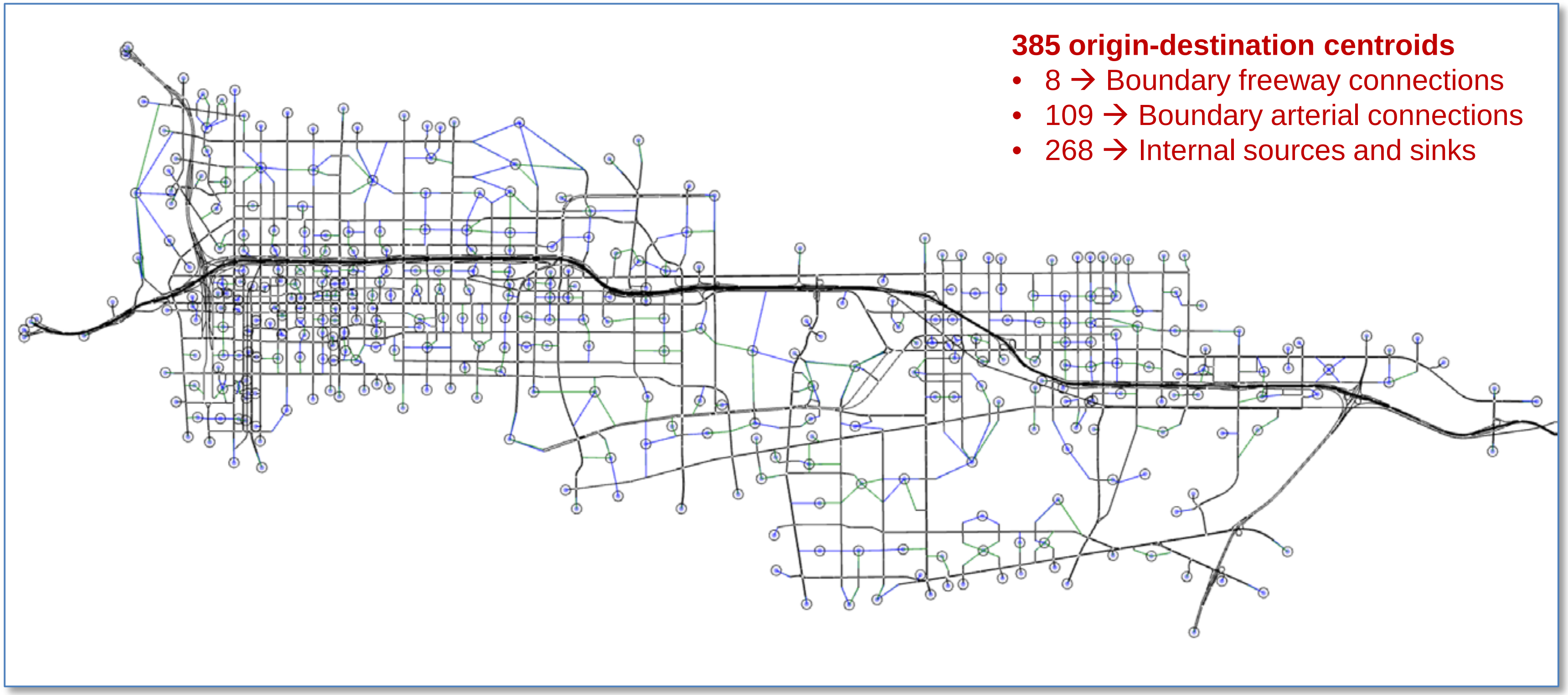
- **Approach 1 - Specification of approach traffic flows and turn percentages at intersections**
  - Vehicles move through the network without a clear destination
  - At each intersection, vehicles determine whether they go straight, turn right or turn left based on probabilities tied to observed data
- **Approach 2 - Definition of origin-destination flow matrices**
  - Vehicles travel across a network based on their defined origin and destination
  - Vehicles typically assigned to the route, or routes, having the lowest cost

Demand Modeling Approach

- **Similar to other leading commercial models, Aimsun uses origin-destination matrices to model traffic demand**
  - Provides greater flexibility in modeling routing applications
- **Key modeling decisions**
  - Origin and destination nodes to include
    - Nodes at network boundaries representing incoming and outgoing traffic
    - Nodes representing traffic sources and sinks within the network
  - Need to keep the number of nodes to a practical minimum
    - Simplifies data processing

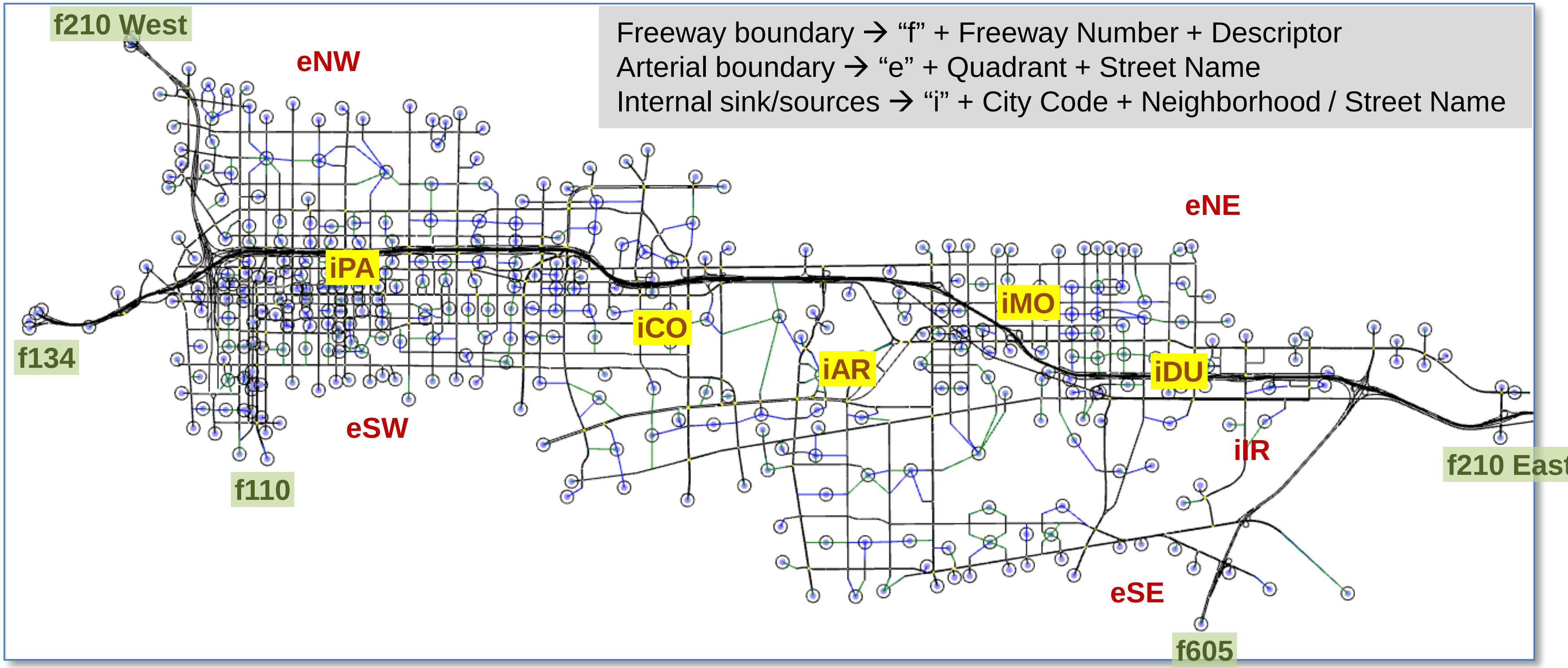
Modeling of Trip Origins and Destinations

- Resulting origin-destination modeling



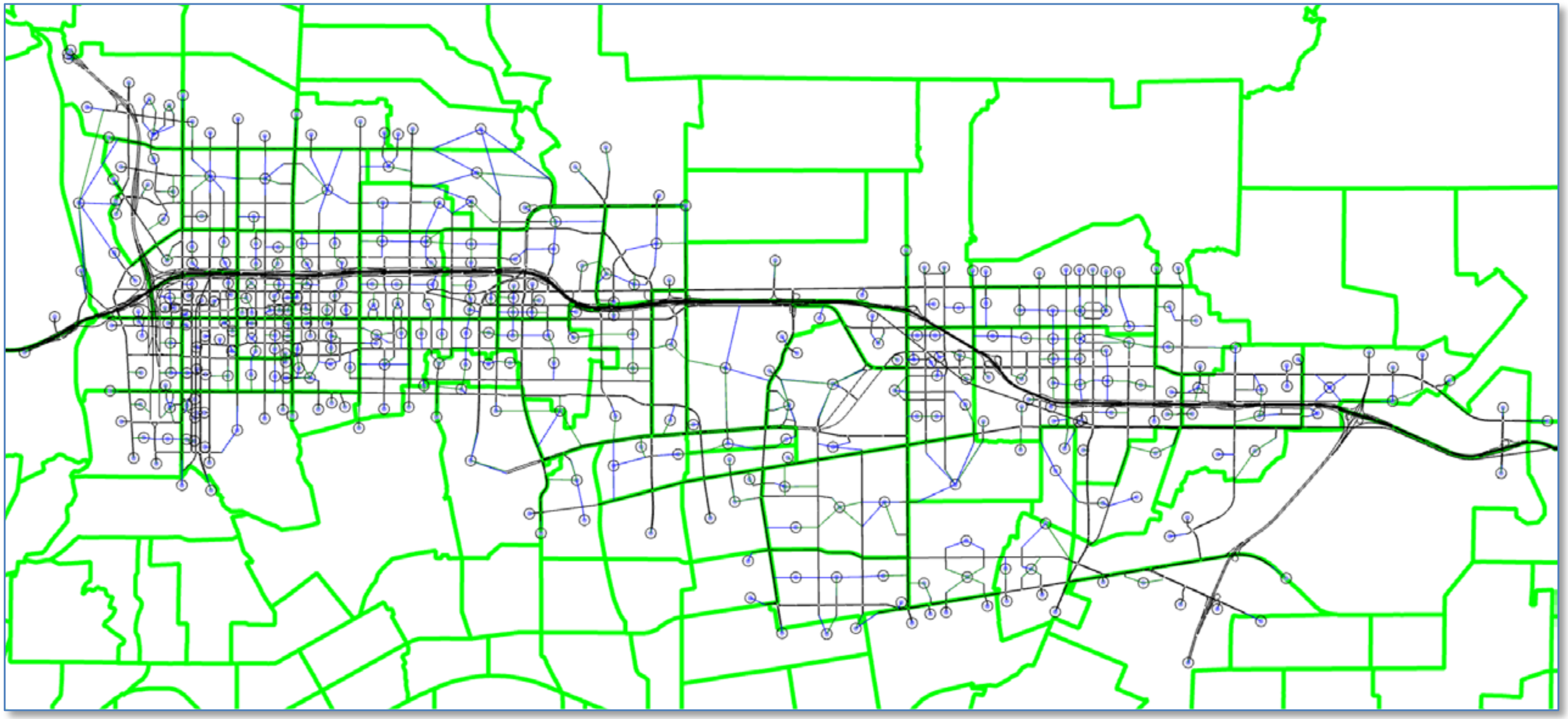
Modeling of Trip Origins and Destinations

- Labeling of centroids for I-210 Corridor



Modeling of Trip Origins and Destinations

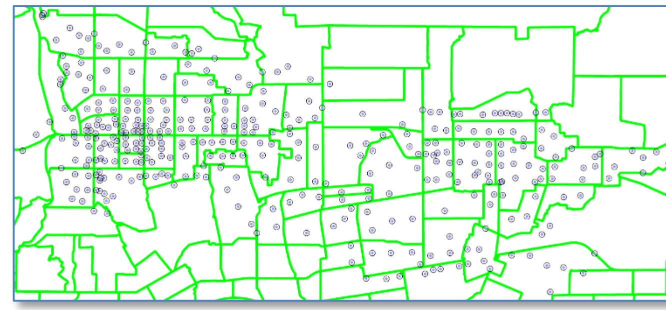
- Correspondence between centroids and traffic analysis zones

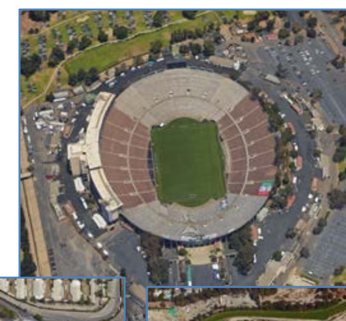


Modeling of Trip Origins and Destinations

- **Best practice:**
  - Centroids are grouped by their corresponding geographical Traffic Analysis Zones (TAZ)
    - Simplify conversion of data obtained from regional travel demand models
  - Specific centroids for elements that may be the focus of specific analyses
    - Parking facilities
    - Events centers

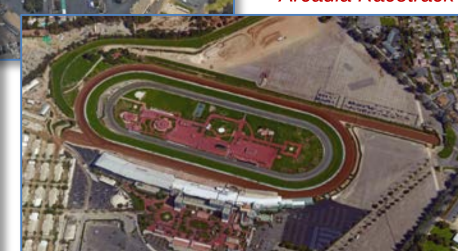
SCAG Traffic Analysis Zones





Rose Bowl

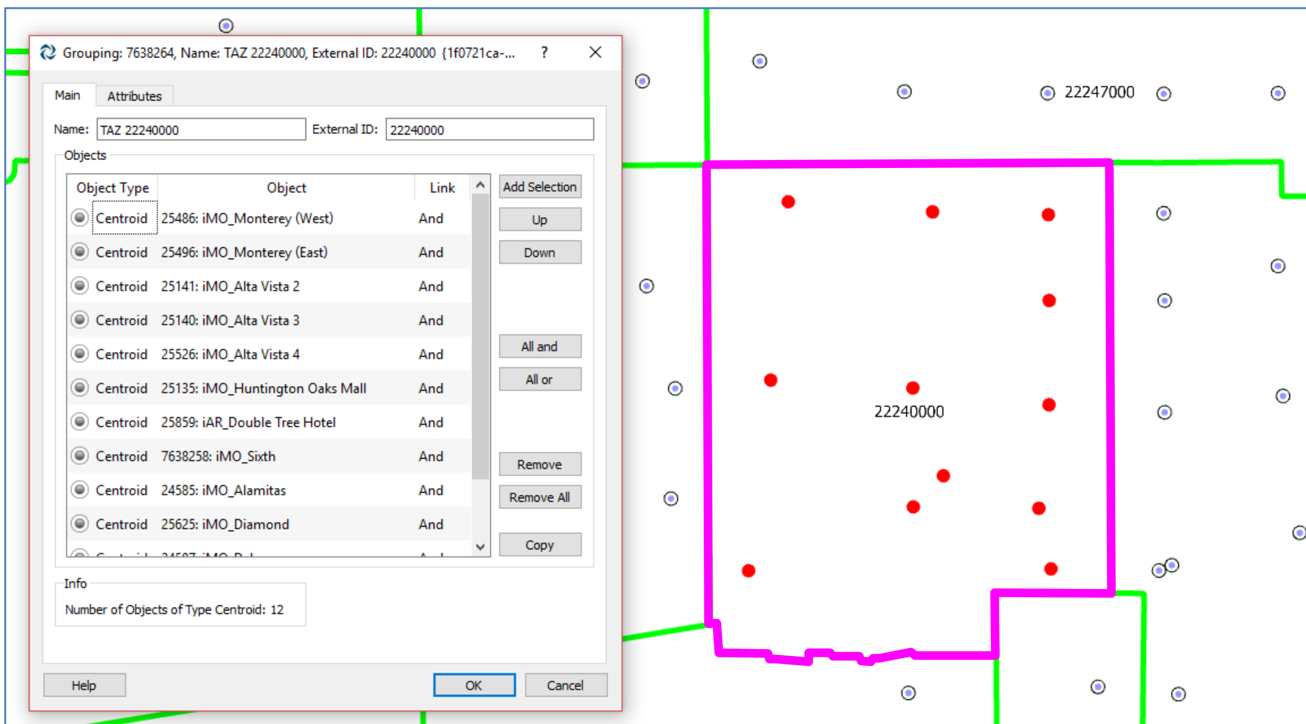
Arcadia Racetrack



Westfield Mall

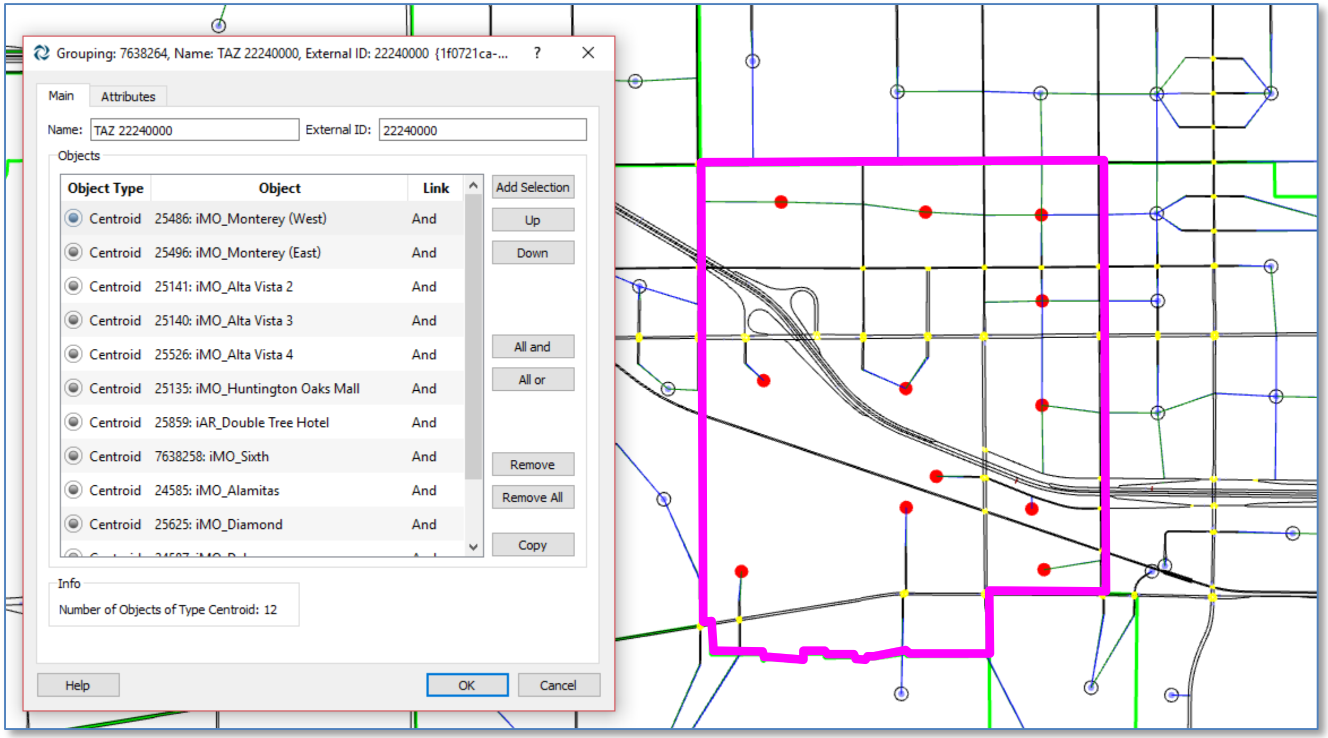
Demand Data Disaggregation

- Except for special cases, demand for each TAZ is split equally among centroids in the TAZ



Demand Data Disaggregation

- Centroid may be connected to multiple places in the network
- Flow allocation from centroid to network entrance is case-by-case



Demand Data Sources

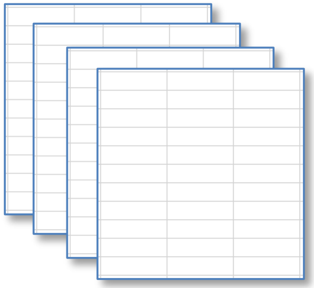
- **OD trip matrices from regional travel demand model**
  - SCAG's 2012 TransCAD
- **Traffic studies**
  - Flows and turning counts from ~21 studies
- **Traffic flow data from traffic monitoring systems**
  - Volume data from PeMS
  - Volume data from mid-block / advanced / stop line traffic detectors
- **Emerging data sources**
  - Tracking data from probe vehicles / cell towers

Estimation of O-D Trip Patterns

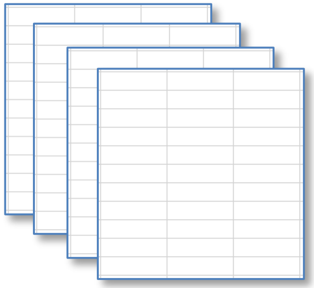
- **Leading simulation models generally provide functions to estimate O-D trip patterns from observed traffic counts**
  - Mathematical problem with multiple possible solutions
  - Solution search made more difficult by inconsistent data
  - Requires a lot of judgement calls
- **Best to start with a seed matrix**
  - Aimsun developers suggest that using O-D matrix from regional travel demand model is usually the best starting point
  - Limited research done to date on how to leverage emerging data sources:
    - Probe vehicle data
    - Cellular phone data records

How Many Matrices to Develop?

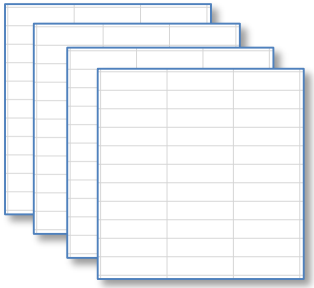
- **Which day(s) to model?**
  - Average weekday
  - Individual weekdays
  - Average Saturday
  - Average Sunday
  - Hard Holidays
  - Soft Holidays



- **What period of day to model?**
  - AM peak period
  - PM peak period
  - Midday
  - Evening/night



- **Which types of vehicles**
  - Single-occupancy passenger cars
  - High-occupancy passenger cars
  - Medium-duty truck
  - Heavy-duty trucks



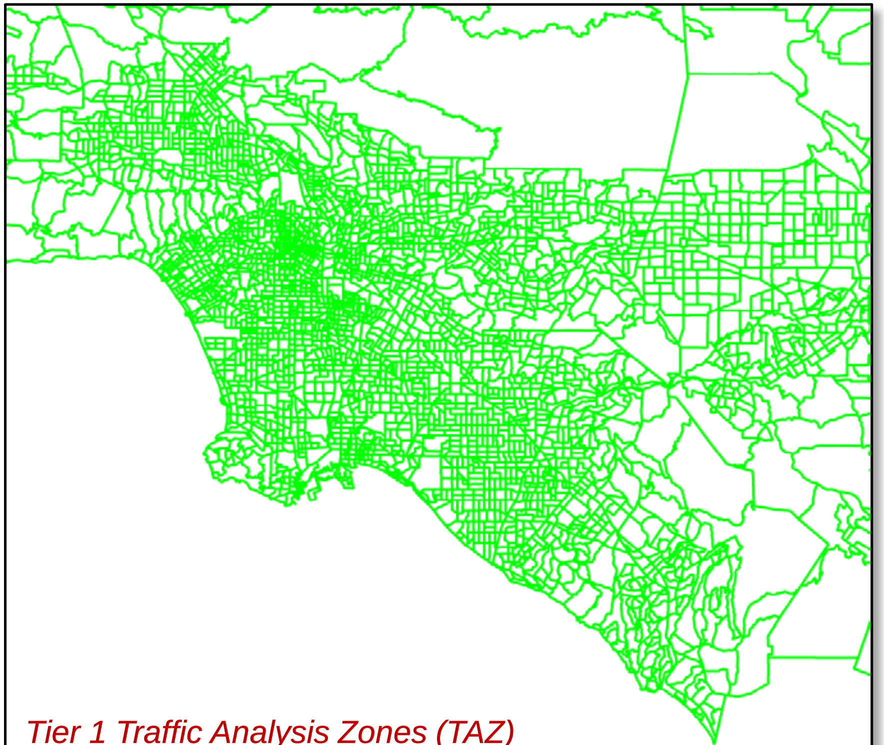
Demand Elements and Examples

- **Day types**
  - Weekday
  - Weekend
- **Vehicle types**
  - Cars
  - HOVs
  - Trucks
- **Trip categories**
  - General
  - Eastbound
  - Westbound

- **Time Periods**
  - AM
  - PM
- **Profiles**
  - Time slicing appropriate for different trip categories
- **Scale factors**
  - Fine tuning adjustments for day subtype, or for incidents

Data from SCAG Regional Demand Model

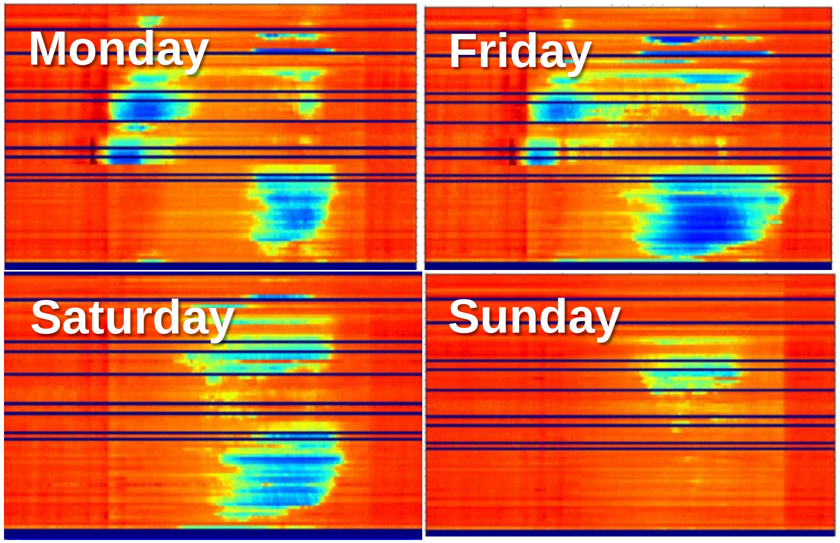
- **Average weekday O-D trip matrices at TAZ level**
- **Time periods**
  - AM Peak: 6:00 AM - 9:00 AM
  - Midday: 9:00 AM - 3:00 PM
  - PM Peak: 3:00 PM - 7:00 PM
  - Evening: 7:00 PM - 9:00 PM
  - Night: 9:00 PM - 6:00 AM
- **Vehicle types**
  - HOV non-user – 1 rider (drive alone)
  - HOV non-user – 2 riders
  - HOV non-user – 3 riders
  - HOV user – 2 riders
  - HOV user – 3 riders
  - Light truck
  - Medium truck
  - Heavy truck



Tier 1 Traffic Analysis Zones (TAZ)

Day Types

- **Number of day types determined by cluster analysis**
  - Initial analysis based on PeMS suggests the following minimum categorization
    - Ave Weekday (Mon-Thurs)
    - Friday
    - Saturday
    - Sunday
    - Hard holiday
    - Soft holiday



- **Differences within a cluster can be represented by combinations of scale factors and profiles**

Extended Vehicle Types

- **4 vehicle types modeled**
  - Car
  - HOV
  - Medium truck
  - Heavy truck

4 types X 3 categories

↓

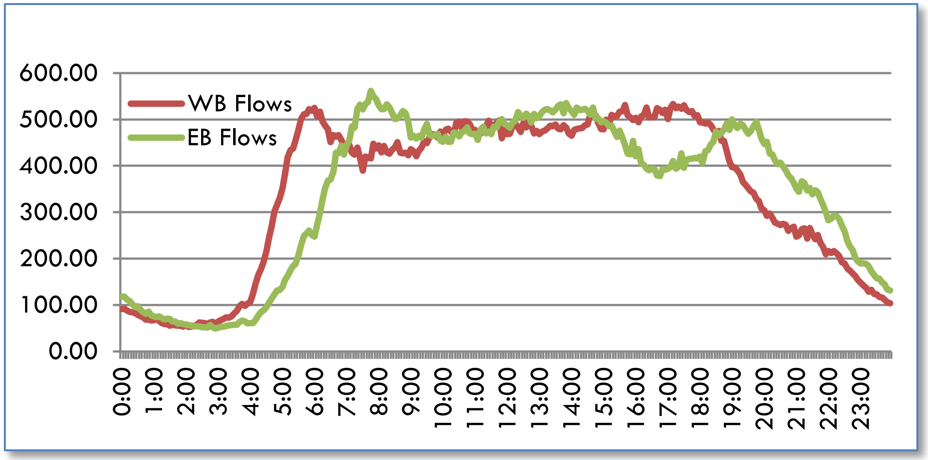
12 extended vehicle types

- **3 trip categories to increase flexibility**
  - General trips
  - Eastbound external-external trips
    - I-210 to I-210 E
    - I-210 to I-605 S
    - SR-134 to I-210 E
    - SR-134 to I-605 S
    - I-605 N to I-210 E
  - Westbound external-external trips
    - I-210 to I-210 W
    - I-210 to SR-134
    - I-210 to I-605 S
    - I-605 N to I-210 W
    - I-605 N to SR-134

Time-slicing

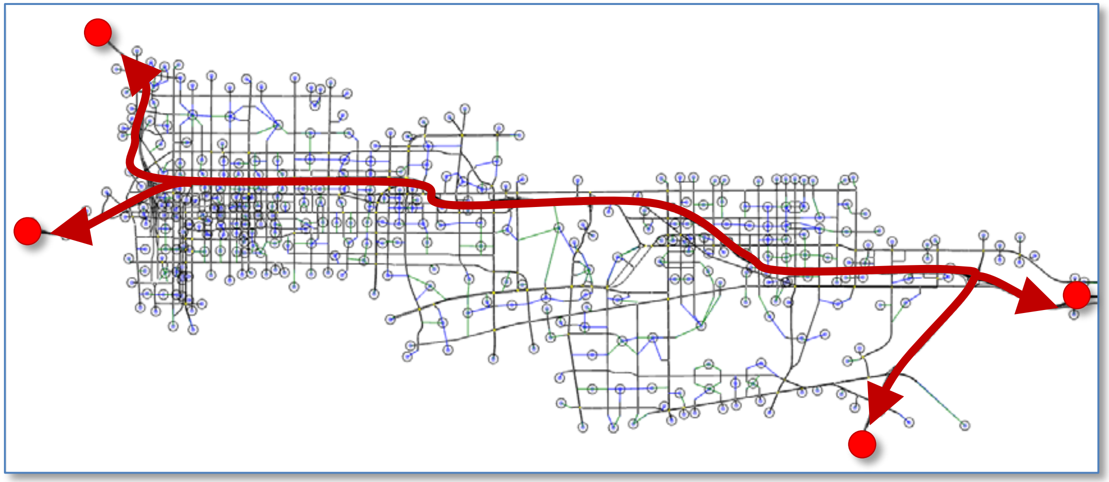
- Time granularity of 15 min
  - 96 points in a 24-hour time profile
  - Trips from each of the 5 SCAG time periods will be distributed based on diurnal profiles
- Three diurnal profiles
  - One profile for each category:
    - General
    - Eastbound external-external,
    - Westbound external-external

Sample of 5-min flows on I-210



Demand prediction

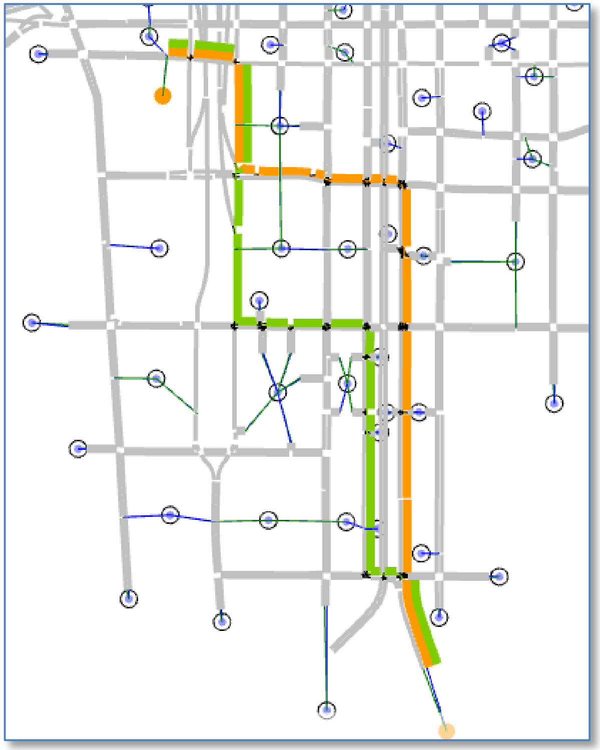
- Key destinations such as external-external flows at main gates are disaggregated by extended vehicle types
- Scaling of corridor traffic based on current day conditions
- During incidents, enable targeted scaling to modify expected changes to external-external flows



Route Choice Modeling

Route Selection Modeling

- **Route selection:**
  - Process by which travelers determine which set of roadway links they will follow to reach their destination
- **Factors affecting route selection**
  - Trip cost calculation
  - Influence of trip cost on route selection
- **I-210 corridor provide drivers with multiple possible paths → Increases sensitivity to route selection modeling**

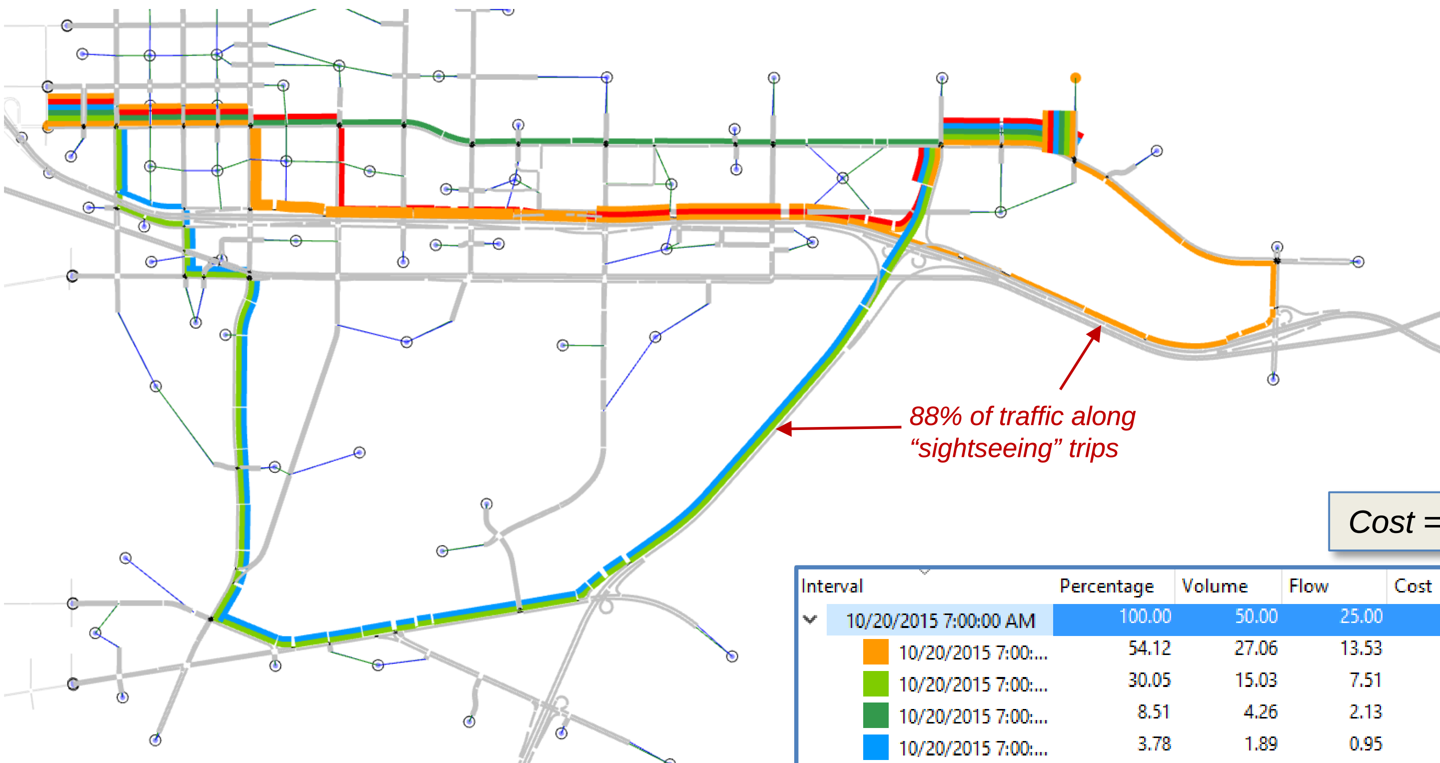


Trip Cost Calculation

- **By default, simulation models typically consider travel time as the only factor affecting route selection**
  - OK for small networks
  - Can create issues in large networks, as routes with significant different length can have similar travel time due to differences in speed limits, traffic control effects
  - Can push a significant proportion of travelers to choose longer route
- **Next refinement is to add travel distance as a factor**
  - Tends to prevent vehicles from choosing "sightseeing" routes
  - Requires some custom programming

Trip Cost Calculation

- **Example: Route selection based solely on travel time**

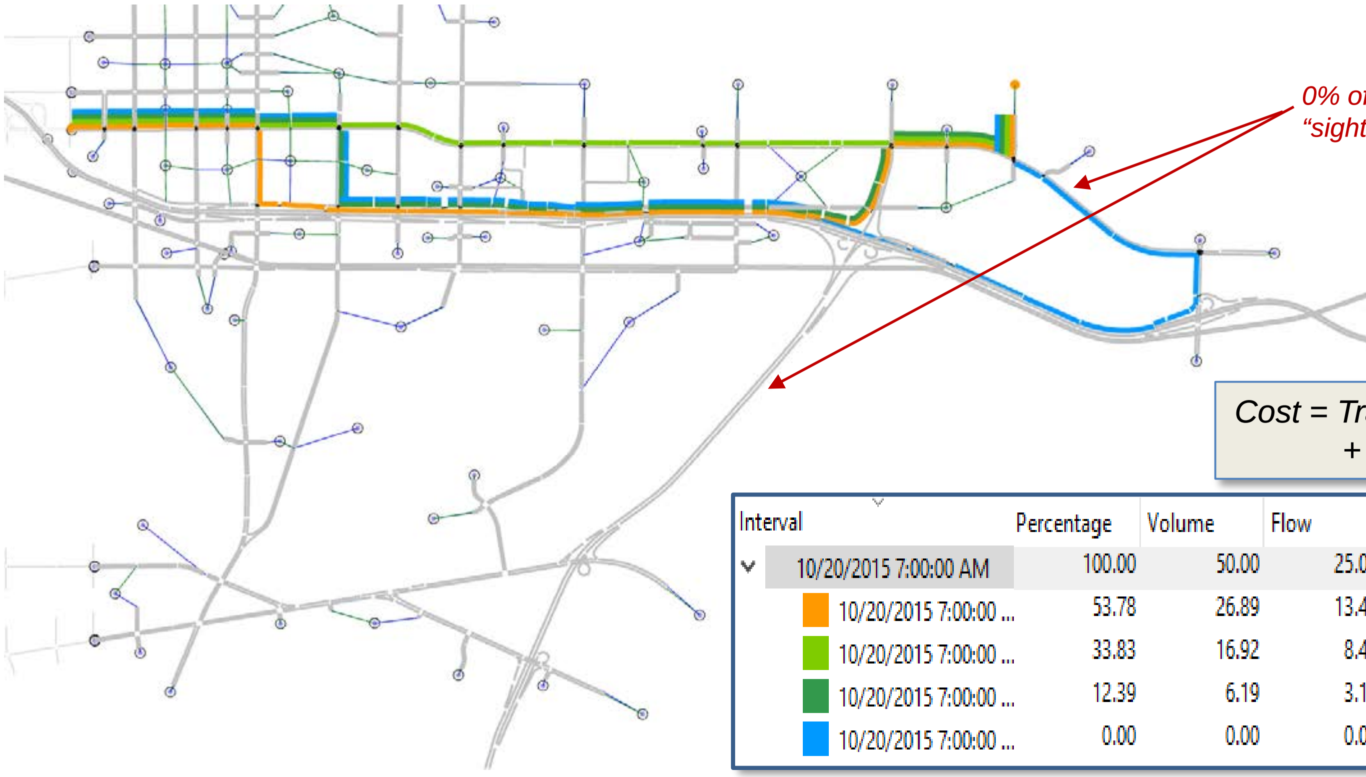


Cost = Travel Time

Interval	Percentage	Volume	Flow	Cost	Distance
10/20/2015 7:00:00 AM	100.00	50.00	25.00	15.93	27974.00
10/20/2015 7:00:...	54.12	27.06	13.53	15.92	24081.53
10/20/2015 7:00:...	30.05	15.03	7.51	15.93	36257.73
10/20/2015 7:00:...	8.51	4.26	2.13	15.93	21317.91
10/20/2015 7:00:...	3.78	1.89	0.95	15.93	36283.00
10/20/2015 7:00:...	3.48	1.74	0.87	15.93	24126.36
10/20/2015 7:00:...	0.06	0.03	0.01	17.10	33178.96

Trip Cost Calculation

- **Example: Route selection considering travel time and distance**



Cost = Travel Time
+ 1.0 * Distance

Interval	Percentage	Volume	Flow	Cost	Distance
10/20/2015 7:00:00 AM	100.00	50.00	25.00	22.64	23152.19
10/20/2015 7:00:00 ...	53.78	26.89	13.44	22.64	24081.53
10/20/2015 7:00:00 ...	33.83	16.92	8.46	22.64	21317.91
10/20/2015 7:00:00 ...	12.39	6.19	3.10	22.64	24126.36
10/20/2015 7:00:00 ...	0.00	0.00	0.00	26.74	33223.80

Trip Cost Calculation

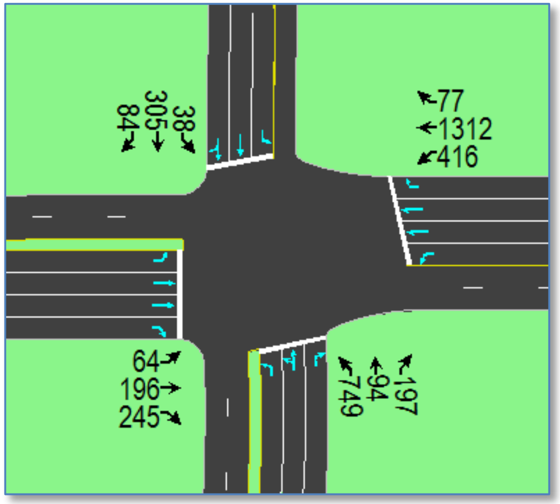
- **Further refinement: factoring traveler preferences**
  - For freeway and arterial trips with similar travel times → motorists tend to prefer using the freeway
  - Motorists may be willing to travel extra distance to stay on a freeway
  - HOV vehicles have extra incentive to use HOV lanes

Static traffic assignment trip costs

Arterials:	*Travel Time + 1.00 * Distance + Ramp Meter Penalty*
Freeways – Main lanes:	*Travel Time + 0.85 * Distance + Ramp Meter Penalty*
Freeway - HOV lanes:	*Travel Time + 0.80 * Distance + Ramp Meter Penalty*

Routing Data Sources

- **Traditional sources**
  - Volume along roadway segments
  - Turning counts at intersections
  - Observations from traffic managers



No direct observations of paths taken

Paths followed by vehicles inferred from observed data

Routing Data Sources

- Emerging sources
  - Tracking data from equipped vehicles (probe vehicles)
  - Tracking data from GPS-equipped smartphones
  - Tracking data cellular phone network operators

- Potential benefits
  - Direct observation of travel paths
- Potential issues
  - GPS location accuracy
  - Distinguishing phones carried onboard vehicles and by pedestrians in congested urban areas
  - Distinguishing multiple phones being tracked from same vehicle

Routing Assumptions – Base Model

- **Initial distribution of route selection models within simulated traffic fleet**
  - 80% of passenger cars follow distribution of shortest paths produced by Dynamic User Equilibrium (DUE) assignment
    - Up to 3 paths considered between each O-D pair
  - 20% of passenger cars able to recalculate paths en-route
    - C-Logit model
- **Slight variations for medium and heavy trucks**
- **Percentages to be adjusted during AMS model calibration**

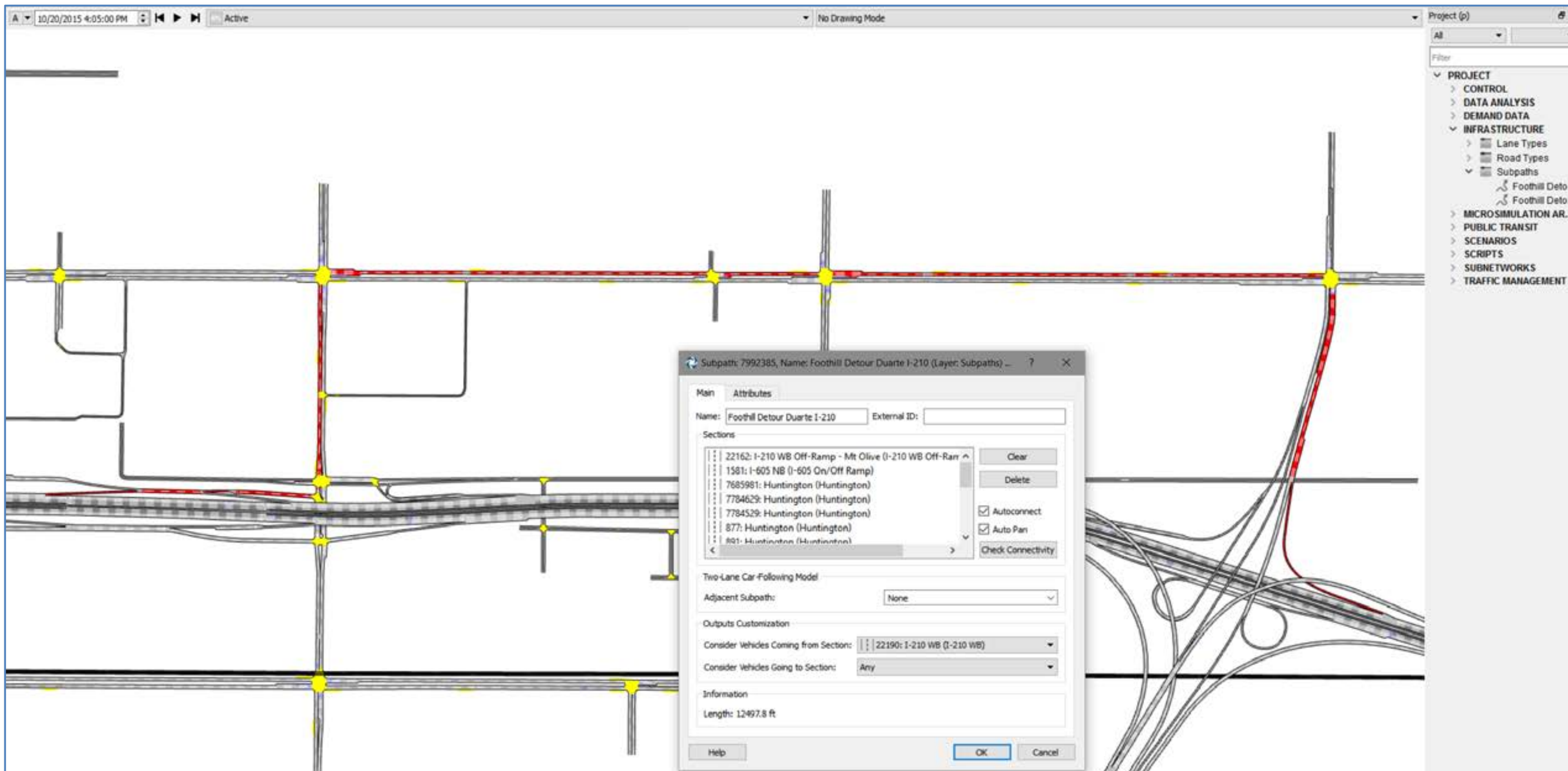
Response Planning Modeling

Response Plan Modeling Elements

- Detours
- Driver responses
- Response timing plans

Incident Response – Modeling of Detours

- Identification of all possible detours in Aimsun



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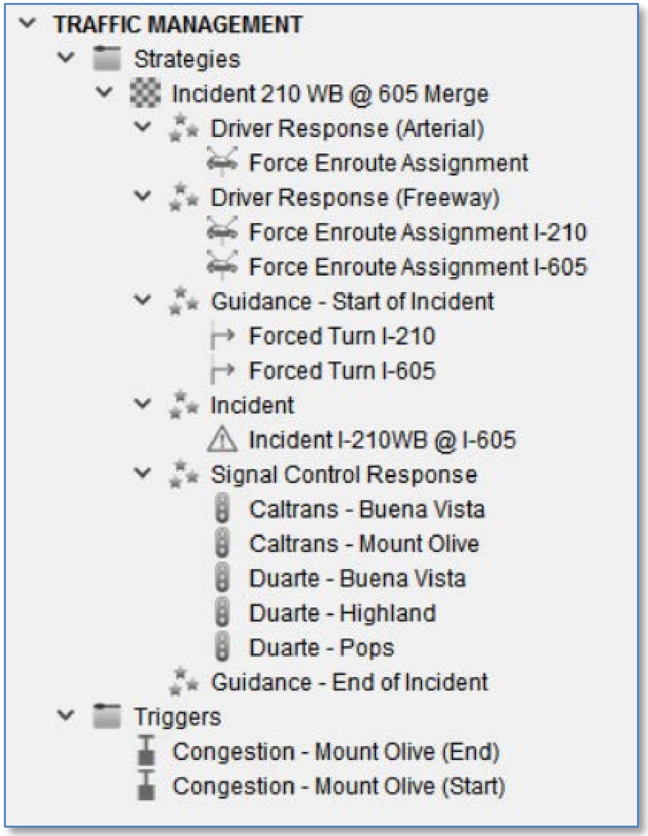
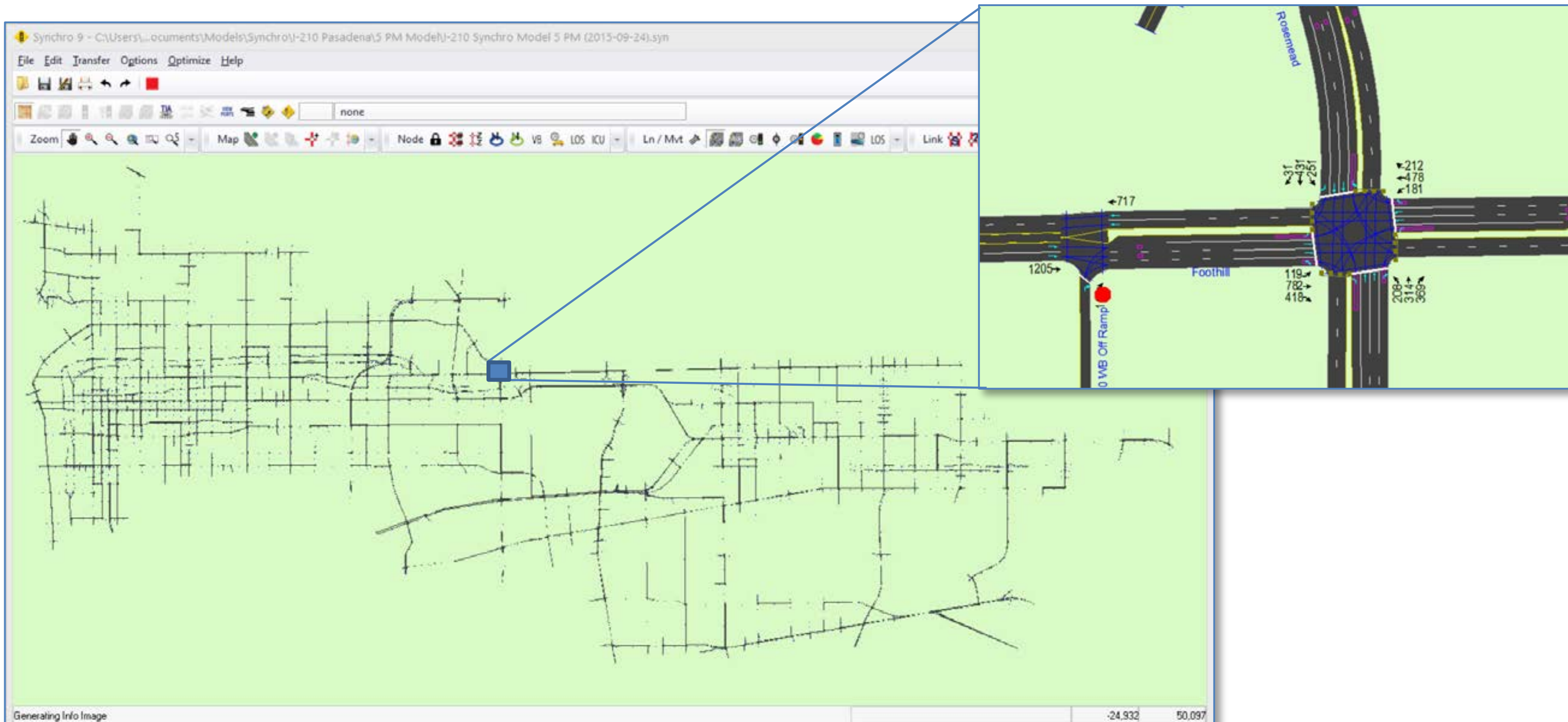
Incident Response – Driver Behavior

- **Parameters to be defined for modeling incidents and response plans**
  - Locations where motorists receive guidance
  - Detour route(s) followed
  - % drivers accepting guidance
  - % other drivers adjusting their route based on observed traffic conditions
  - Event triggering driver responses
- **Percentages to be determined based on literature review, Berkeley research, modeling experience, etc.**



Incident Response – Timing Plans

- Preliminary timing plans to be developed using available Synchro model of corridor



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Model Execution

Running Large Scale Models

- **Execution time is a key concern when running large simulation models**
  - Not an issue in conducting off-line analyses
  - Critical issue: model is to be used in a real-time operational context
- **Traditional solution**
  - Running the model on computers with high processing power
  - Parallelizing the simulation process to allow multiple threads
- **Emerging solution**
  - Moving execution to the cloud, where computing power could be scaled as needed

Aimsun now running on Amazon Cloud

Research and Partnering

AMS and Research Themes

- Machine Learning for Calibration and Control
- Data Quality Algorithms
- Estimation Methods
- Data Fusion Methods
- Call Data Records (CDRs) for OD
- Probe Data for ODME, Speed and Density
- Route Choice
- Driver Response to Guidance or Incentives

I-210 Corridor as a Center for Future Transportation Innovation

- **The I-210 Corridor will be uniquely positioned**
  - Well studied, well instrumented, well understood, and well modeled
  - Centralized archives of high quality data over diverse operating conditions
- **Leveraging these assets, the I-210 will be an ideal corridor for future innovation and new technologies**
  - Connected and automated vehicles
  - Transportation as a service
  - Coordination between public and private modes
  - Integration with smart cities and regions
  - New partnerships and new possibilities

Partnerships and Cooperation

- **To push forward the state-of-the-art and the state-of-practice we plan to share our:**
  - Models
  - Data
  - Algorithms
- **We are interested in partnering with:**
  - Stakeholders
  - Academic institutions
  - Federal and state governments
  - Industry partners

Thank you

Questions for discussion?