I-210 Connected Corridors Pilot

Analysis, Modeling and Simulation Review
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

Extent of Study Area

Phase 1
Project Area

Phase 2
Addition
I-210 Pilot ICM: Managed Roadways
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
Response Planning Needs
Action items associated with a response plan

- Detour Routes
  - Passenger Cars
  - Trucks
  - Buses

- Intersection Signal Control Requests
  - On routes
  - Not on routes

- Ramp Meter Control Requests
  - On routes
  - Not on routes

- Equipment Requests
  - Trucks
  - Cars
  - Portable Equipment

- Personnel Requests
  - Traffic Engineers
  - Safety Personnel
  - Others

- Information Dissemination
  - Corridor Operators
  - Travelers

- Fixed Devices
  - CMS Messages
  - HAR Messages
  - 511 Services

- Portable Devices
  - 3rd Party Info Providers

- Roadway Operators
  - Transit Operators
  - Parking Operators
  - First Responders
  - Emergency Services

- Transit Operators
  - Parking Operators
  - First Responders
  - Emergency Services
~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

Flow along detour
# Performance Metrics Produced by Aimsun

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

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** $\rightarrow$ reduced situational awareness
    - Unable to locate routes with available capacity
  - **Bad data** $\rightarrow$ bad decisions
    - $\rightarrow$ Bad management and worse traffic
    - $\rightarrow$ 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

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

- 459 signalized intersections
- 45 freeway ramp meters
- ~1000 lane miles
- ~5000 traffic detectors
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

- **Microsimulation (time-based)**
- **Mesosimulation (event-based)**
- **Macrosimulation (flow-based)**
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
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
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
**Traffic Signals – Modeling Considerations**

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

| Intersection     | Main Street | Cross Street | 1200 | 1300 | 1400 | 1500 | 1600 | 1700 | 1800 | 1900 | 2000 | 2100 | 2200 | 2300 | 0000 | 0100 | 0200 | 0300 | 0400 | 0500 | 0600 | 0700 | 0800 | 0900 | 1000 | 1100 | 1200 |
|------------------|-------------|--------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Fair Oaks Ave    | Maple St    | E   | E   | I   | 1   | I   | 1   | E   | E   | E   | E   | E   | E   | E   | E   | E   | E   | E   | E   | E   | E   | E   | E   | E   | E   | E   | E   | E   | E   |
| Fair Oaks Ave    | Country St  | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   |
| Fair Oaks Ave    | College St  | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   |
| Fair Oaks Ave    | Minne St    | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   |
| Fair Oaks Ave    | Cypress St  | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   |
| Fair Oaks Ave    | Ivy St      | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   |
| Fair Oaks Ave    | Valley St   | E   | E   | I   | I   | I   | I   | E   | E   | E   | E   | E   | E   | E   | E   | E   | E   | E   | E   | E   | E   | E   | E   | E   | E   | E   | E   | E   | E   |
| Fair Oaks Ave    | Cypress St  | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   |
| Fair Oaks Ave    | College St  | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   |
| Fair Oaks Ave    | Cypress St  | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   |
| Fair Oaks Ave    | College St  | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   |
| Fair Oaks Ave    | Cypress St  | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   |
| Fair Oaks Ave    | College St  | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   |
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| Fair Oaks Ave    | College St  | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   |
| Fair Oaks Ave    | Cypress St  | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   |
| Fair Oaks Ave    | College St  | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   |
| Fair Oaks Ave    | Cypress St  | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   |
| Fair Oaks Ave    | College St  | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   |
| Fair Oaks Ave    | Cypress St  | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   |
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| Fair Oaks Ave    | Cypress St  | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   | N   |
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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**

Diagram showing the typical detector configuration for ramp metering systems, including Mainline Sensors, HOV Lane Sensor, and various other components such as Off-ramp Count Sensor, Queue Sensor, and Ramp Meter Controller.
Ramp Metering – Modeling Considerations

- Ramp metering schedule
- Variations in metering operations across ramps

### I-210 Ramp Metering Rate Schedule

| Freeway   | Ramp   | 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 | 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 |
|-----------|--------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
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.

```c
if (TODate > 0):
    # Ramp metering rate defined for period of day
    if (ContentOption & 1):
        # control option set to LMR
        PlanType = getCurrentPlanType(timeTod, MeterID)
        CriticalGroup = CriticalGroupArray[tod]
        CriticalVolume = CriticalVolumeArray[tod]
        if (PlanType = "B"):
            CriticalGroup = CriticalGroupArray[tod]
            CriticalVolume = CriticalVolumeArray[tod]

    if (AvgMainMainRate > CriticalGroup):
        if (NotMainMainLanes > 0):
            LMRate = (MainMainRate * (CriticalVolume - AvgMainMainLanes))/3 * 100.
        if (LMRate < TODate):
            LMRate = TODate

    if (LMRate > RateMax):
        # LM rate greater than maximum metering rate permissible --> go to full green
        GreenBallRate = HMainLanes - RateLimitArray[tod] + GreenBallRate,
        GreenBallRate = TODate,
        RateMax = RateMax,
        timeTod = timeTod,
        axyle;

    else:
        # LM rate is within permitted values --> implement calculated valid
        Error = EICChangeRatesFlowMeteringByPercent(MeterID, timeTod, RateMax, RateLimitArray[tod], LMRate, RateMax, timeTod, axyle);
        axyle;

    else:
        # One-minute average mainline occupancy vs. critical occupancy --> implement TOD rate
        Error = EICChangeRatesFlowMeteringByPercent(MeterID, timeTod, RateMax, TODate, RateLimitArray[tod], RateMax, timeTod, axyle);
        axyle;

    if (ContentOption & 1):
        # control option set to TOD control
        TODControl = TODControlArray[tod]
        TODRate = TODRate,
        timeTod = timeTod,
        axyle;

    else:
        # default control option: TOD control
        TODControl = TODControlArray[tod]
        TODRate = TODRate,
        timeTod = timeTod,
        axyle;

    if (ChangeCode):
        # no ramp metering rate defined for period of day --> set meter to green
        GreenBallRate = HMainLanesArray[tod] * GreenBallRate,
        GreenBallRate = TODRate,
        TODRate = TODRate,
        RateMax = RateMax,
        timeTod = timeTod,
        axyle;

    else:
```
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**
  - Bus stopping in the roadway
  - Bus bays

- **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

Map highlighting existing/proposed intersections with priority/preemption control.
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

- Heavy traffic from Lake on-ramp (~900 vph)
- Heavy entering traffic from three consecutive on-ramps (~1700 vph)
- Traffic weaving to take Sierra Madre exit
- Heavy entering traffic from two consecutive Baldwin on-ramps
- Weaving from mainline traffic trying to get to the outer lanes to take I-605 exit
- Traffic merging at crest of a curve
- Heavy traffic from two consecutive on-ramps (~1000 vph)
- Traffic merging at the crest of a large horizontal curve
- Heavy traffic from two consecutive on-ramps (~1000 vph)
- Traffic merging at the crest of a large horizontal curve
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.
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*
Existing Calibration Guidelines

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

### FHWA Calibration Guidelines

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

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

\(E\) = 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

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

\[ GEH = \sqrt[5]{\frac{(E - V)^2}{0.5(E + V)}} \]

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

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

![Map of main corridor freeway bottlenecks with key and other westbound and eastbound bottlenecks marked.]
## Proposed Calibration Guidelines

### Arterials

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

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

*Over key major intersections

\( E = \) 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
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
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
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
Freeway Estimation Approach
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**

  - Real-time flows and detector occupancies
  - Network
  - Fundamental diagrams
  - Boundary flows
  - Turning movements
  - Data Assimilation
  - CTM-based Models
  - Freeway Traffic State
    - Speeds, densities
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 $\rightarrow$ good estimation results
  - Estimation fills in the blanks, so filter aggressively to remove suspect data
Estimation Running in the Cloud
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
Queue Estimation

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

[Diagram showing estimated queue for left-turn, advance detector 1, advance detector 2, and resulting queue estimates]
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 $\rightarrow$ 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

<table>
<thead>
<tr>
<th>Weekly Average Data</th>
<th>Eastbound I-210 PM 25 to PM 43.25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality</td>
<td>CD</td>
</tr>
<tr>
<td>May 1-7</td>
<td>n.a.</td>
</tr>
<tr>
<td>May 8-14</td>
<td>n.a.</td>
</tr>
<tr>
<td>May 15-21</td>
<td>n.a.</td>
</tr>
<tr>
<td>May 22-28</td>
<td>n.a.</td>
</tr>
<tr>
<td>May 29-Jun 04</td>
<td>n.a.</td>
</tr>
<tr>
<td>Jun 05-11</td>
<td>n.a.</td>
</tr>
<tr>
<td>Jun 12-18</td>
<td>n.a.</td>
</tr>
<tr>
<td>Jun 19-25</td>
<td>n.a.</td>
</tr>
<tr>
<td>Jun 26-Jul2</td>
<td>n.a.</td>
</tr>
<tr>
<td>Jul3-9</td>
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<tr>
<td>Jul10-16</td>
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<td>Jul17-23</td>
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<tr>
<td>Jul24-30</td>
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<td>Jul31-Aug06</td>
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<td>Aug14-Aug20</td>
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<td>Aug21-Aug27</td>
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<td>Aug28-Sept3</td>
<td>n.a.</td>
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<tr>
<td>Sept4-Sept10</td>
<td>n.a.</td>
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<td>Sept11-Sept18</td>
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<tr>
<td>Sept18-Sept25</td>
<td>n.a.</td>
</tr>
<tr>
<td>Sept25-Oct2</td>
<td>n.a.</td>
</tr>
<tr>
<td>Loops in Category</td>
<td>0</td>
</tr>
</tbody>
</table>
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
Example: Fix requests for detectors assigned to wrong side of freeway or wrong lane

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

VDS 772903 (I-210 EB)  VDS 772902 (I-210 WB)

June 20, 2016

June 21, 2016

Consistent pattern

Consistent pattern

Consistent pattern

Consistent pattern

Difference in morning rush hour onset

Difference in morning rush hour onset
Fixing Freeway Detectors – Example 2

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

**Before**

- July 5, 2016
- Consistent flow difference across successive detectors

**After**

- July 8, 2016
- Count per 5 mins
Fixing Freeway Detectors – Example 3

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

**Before**
- July 5, 2016
- Pattern mismatch during AM Peak
- Unusual high flow at night

**After**
- July 7, 2016

**Graphs:**
- Count per 5 mins
- Time of day

**Legend:**
- 761222
- 770407
- 761214
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

5 lanes in reality
4 lanes in PeMS
Fixing Freeway Detectors – Example 5

- **Mismatch in number of lanes covered**

<table>
<thead>
<tr>
<th>Item</th>
<th>freeway</th>
<th>VDS ID</th>
<th>Name</th>
<th>Type</th>
<th>Lanes in PeMS</th>
<th>Lanes in Google Streetview</th>
<th>Comments</th>
<th>Findings by Caltrans</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I210-W</td>
<td>770568</td>
<td>HAMMOND ST.</td>
<td>Mainline</td>
<td>4</td>
<td>5</td>
<td>Lane count mismatch</td>
<td>Outside of Corridor</td>
</tr>
<tr>
<td>2</td>
<td>I210-W</td>
<td>717107</td>
<td>SANTA ANITA NB</td>
<td>On Ramp</td>
<td>1</td>
<td>2</td>
<td>Lane count mismatch</td>
<td>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 (9/16/16)</td>
</tr>
<tr>
<td>3</td>
<td>I210-W</td>
<td>773194</td>
<td>E OF SECOND</td>
<td>Mainline</td>
<td>4</td>
<td>5</td>
<td>Lane count mismatch</td>
<td>Requested MLS to be added to ATMS (8/5/16)</td>
</tr>
<tr>
<td>4</td>
<td>I210-W</td>
<td>761330</td>
<td>MYRTLE AV</td>
<td>Off Ramp</td>
<td>2</td>
<td>1</td>
<td>Lane count mismatch</td>
<td>2 loops to cover 1 wide lane Requested FR2 to be removed from ATMS (8/11/16)</td>
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<tr>
<td>5</td>
<td>I210-W</td>
<td>785702</td>
<td>HIGHLAND</td>
<td>Mainline</td>
<td>4</td>
<td>5</td>
<td>Lane count mismatch</td>
<td>4 lanes 4 loops: Non-issue (8/11/16) Location identified in photo provided (5/6/16)</td>
</tr>
<tr>
<td>6</td>
<td>I210-W</td>
<td>773206</td>
<td>SB 605 FROM WB 210</td>
<td>Fwy-Fwy</td>
<td>2</td>
<td>3</td>
<td>Lane count mismatch</td>
<td>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)</td>
</tr>
<tr>
<td>7</td>
<td>I210-W</td>
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<td>SAN GABRIEL RIVER</td>
<td>Mainline</td>
<td>4</td>
<td>5</td>
<td>Lane count mismatch</td>
<td>Tedeo is fixing Requested MLS to be added to ATMS (8/5/16)</td>
</tr>
<tr>
<td>8</td>
<td>I210-W</td>
<td>772873</td>
<td>W/D IRWINDALE</td>
<td>Mainline</td>
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<tr>
<td>9</td>
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<td>AZUSA 1</td>
<td>Mainline</td>
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<td>5</td>
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<td>Requested MLS to be added to ATMS (8/23/16)</td>
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<td>10</td>
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<tr>
<td>11</td>
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<td>769774</td>
<td>NB 605 TO EB 210 CON</td>
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<td>2</td>
<td>Mismatch in PeMS only</td>
<td>PeMS issue (8/10/16)</td>
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<tr>
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<td>4</td>
<td>5</td>
<td>Lane count mismatch</td>
<td>Tedeo is fixing Requested MLS to be added to ATMS (8/5/16)</td>
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<tr>
<td>13</td>
<td>I210-E</td>
<td>774990</td>
<td>IRWINDALE 1</td>
<td>Off Ramp</td>
<td>1</td>
<td>2</td>
<td>Lane count mismatch</td>
<td>1 loop functioning; 1 loop missing DLC (8/11/16)</td>
</tr>
<tr>
<td>14</td>
<td>I210-E</td>
<td>718469</td>
<td>CITRUS 2</td>
<td>Mainline</td>
<td>4</td>
<td>5</td>
<td>Lane count mismatch</td>
<td>merging with an on-ramp WILL need to replace ML4 with a wider loop (8/18/16)</td>
</tr>
<tr>
<td>15</td>
<td>SR134-W</td>
<td>769301</td>
<td>EB 210 TO WB 134 #2</td>
<td>Fwy-Fwy</td>
<td>1</td>
<td>2</td>
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<td>Outside of Corridor</td>
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<tr>
<td>16</td>
<td>SR134-E</td>
<td>717605</td>
<td>ORANGE GROVE</td>
<td>Off Ramp</td>
<td>1</td>
<td>2</td>
<td>Lane count mismatch</td>
<td>Outside of Corridor</td>
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</table>
Sensors not returning data

<table>
<thead>
<tr>
<th>Item</th>
<th>Fwy</th>
<th>VDS ID</th>
<th>Name</th>
<th>Type</th>
<th>MS ID</th>
<th>Comments</th>
<th>Findings by Caltrans</th>
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</thead>
<tbody>
<tr>
<td>17</td>
<td>1605-S</td>
<td>766926</td>
<td>605 SB TO ARROW WB</td>
<td>Off Ramp</td>
<td>4428</td>
<td>Appear permanently broken</td>
<td>Bad loop (8/17/16)</td>
</tr>
<tr>
<td>18</td>
<td>1605-S</td>
<td>766925</td>
<td>605 SB TO ARROW EB</td>
<td>Off Ramp</td>
<td>4428</td>
<td>Appear permanently broken</td>
<td>Bad loop (8/17/16)</td>
</tr>
<tr>
<td>19</td>
<td>1605-S</td>
<td>773798</td>
<td>ROUTE 605/ ROUTE 210</td>
<td>Mainline</td>
<td>2443</td>
<td>Appear permanently broken</td>
<td>Solar panel issue (8/17/16)</td>
</tr>
<tr>
<td>20</td>
<td>1605-S</td>
<td>774260</td>
<td>MT OLIVE TO SB 605</td>
<td>Coll/Dist</td>
<td>4430</td>
<td>Appear permanently broken</td>
<td>Bad loop (8/17/16)</td>
</tr>
<tr>
<td>21</td>
<td>1605-N</td>
<td>773807</td>
<td>ROUTE 605/ ROUTE 210</td>
<td>Mainline</td>
<td>2443</td>
<td>Appear permanently broken</td>
<td>Solar panel issue (8/17/16)</td>
</tr>
<tr>
<td>22</td>
<td>1210-W</td>
<td>761322</td>
<td>HILZ</td>
<td>HOV</td>
<td>4308</td>
<td>Appear permanently broken</td>
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<tr>
<td>23</td>
<td>1210-W</td>
<td>717645</td>
<td>SAN GABRIEL</td>
<td>HOV</td>
<td>4306</td>
<td>Appear permanently broken</td>
<td>Bad Loop (9/30/16)</td>
</tr>
<tr>
<td>24</td>
<td>1210-W</td>
<td>717658</td>
<td>ROSEMEAD 2</td>
<td>Off Ramp</td>
<td>4569</td>
<td>Appear permanently broken</td>
<td>Bad Loop (9/30/16)</td>
</tr>
<tr>
<td>25</td>
<td>1210-W</td>
<td>717662</td>
<td>BALDWIN SB</td>
<td>Off Ramp</td>
<td>4303</td>
<td>Appear permanently broken</td>
<td>Misconfigured (9/30/16)</td>
</tr>
<tr>
<td>26</td>
<td>1210-W</td>
<td>717665</td>
<td>BALDWIN 2</td>
<td>HOV</td>
<td>4532</td>
<td>Appear permanently broken</td>
<td>Controller Down (9/30/16)</td>
</tr>
<tr>
<td>27</td>
<td>1210-W</td>
<td>717668</td>
<td>SANTA ANITA SB</td>
<td>Off Ramp</td>
<td>4301</td>
<td>Appear permanently broken</td>
<td>Misconfigured (9/30/16)</td>
</tr>
<tr>
<td>28</td>
<td>1210-W</td>
<td>764144</td>
<td>SANTA ANITA 2</td>
<td>HOV</td>
<td>4300</td>
<td>Appear permanently broken</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>1210-W</td>
<td>773196</td>
<td>E OF SECOND</td>
<td>HOV</td>
<td>2117</td>
<td>Appear permanently broken</td>
<td>Communications issue (9/30/16)</td>
</tr>
<tr>
<td>30</td>
<td>1210-W</td>
<td>773194</td>
<td>E OF SECOND</td>
<td>Mainline</td>
<td>2117</td>
<td>Appear permanently broken</td>
<td>Communications issue (9/30/16)</td>
</tr>
<tr>
<td>31</td>
<td>1210-W</td>
<td>761350</td>
<td>MYRTLE AV</td>
<td>Off Ramp</td>
<td>4298</td>
<td>Appear permanently broken</td>
<td>Good-Fixed (9/30/16)</td>
</tr>
<tr>
<td>32</td>
<td>1210-W</td>
<td>772875</td>
<td>W/O IRWINDALE</td>
<td>HOV</td>
<td>2120</td>
<td>Appear permanently broken</td>
<td>Good-Fixed (8/12/16)</td>
</tr>
<tr>
<td>33</td>
<td>1210-W</td>
<td>761388</td>
<td>AZUSA 1</td>
<td>HOV</td>
<td>4290</td>
<td>Appear permanently broken</td>
<td>Conduit Damaged (9/30/16)</td>
</tr>
<tr>
<td>34</td>
<td>1210-W</td>
<td>717678</td>
<td>AZUSA 1</td>
<td>Mainline</td>
<td>4290</td>
<td>Appear permanently broken</td>
<td>Conduit Damaged (9/30/16)</td>
</tr>
<tr>
<td>35</td>
<td>1210-W</td>
<td>716610</td>
<td>AZUSA SB</td>
<td>On Ramp</td>
<td>4290</td>
<td>Appear permanently broken</td>
<td>Conduit Damaged (9/30/16)</td>
</tr>
<tr>
<td>36</td>
<td>1210-E</td>
<td>773131</td>
<td>FAIR OAKS OFF</td>
<td>Fwy-Fwy</td>
<td>2547</td>
<td>Appear permanently broken</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>1210-E</td>
<td>761098</td>
<td>LAKE 2</td>
<td>HOV</td>
<td>4248</td>
<td>Appear permanently broken</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>1210-E</td>
<td>769272</td>
<td>HILL AVE OFF</td>
<td>Off Ramp</td>
<td>2575</td>
<td>Appear permanently broken</td>
<td>Missing Cabinet, Maintenance will fix (5/30/16)</td>
</tr>
<tr>
<td>39</td>
<td>1210-E</td>
<td>716589</td>
<td>HILL NB</td>
<td>On Ramp</td>
<td>4249</td>
<td>Appear permanently broken</td>
<td>Fixed - Shows all Green in PMs (9/30/16)</td>
</tr>
<tr>
<td>40</td>
<td>1210-E</td>
<td>763908</td>
<td>SIERRA MADRE V1</td>
<td>Off Ramp</td>
<td>2568</td>
<td>Appear permanently broken</td>
<td>SD2 change to SD3 - change form sent (9/30/16)</td>
</tr>
<tr>
<td>41</td>
<td>1210-E</td>
<td>773193</td>
<td>E OF SECOND</td>
<td>Mainline</td>
<td>2117</td>
<td>Appear permanently broken</td>
<td>Communications issue (9/30/16)</td>
</tr>
<tr>
<td>42</td>
<td>1210-E</td>
<td>773195</td>
<td>E OF SECOND</td>
<td>HOV</td>
<td>2117</td>
<td>Appear permanently broken</td>
<td>Communications issue (9/30/16)</td>
</tr>
<tr>
<td>43</td>
<td>1210-E</td>
<td>761128</td>
<td>HUNTINGTON 1</td>
<td>Mainline</td>
<td>4257</td>
<td>Appear permanently broken</td>
<td>Fixed - Shows all Green in PMs (9/30/16)</td>
</tr>
<tr>
<td>44</td>
<td>1210-E</td>
<td>761126</td>
<td>HUNTINGTON 1</td>
<td>HOV</td>
<td>4257</td>
<td>Appear permanently broken</td>
<td>Fixed - Shows all Green in PMs (9/30/16)</td>
</tr>
<tr>
<td>45</td>
<td>1210-E</td>
<td>761130</td>
<td>HUNTINGTON WB</td>
<td>Off Ramp</td>
<td>4257</td>
<td>Appear permanently broken</td>
<td>SD4 bit needs to be turned on (9/30/16)</td>
</tr>
<tr>
<td>46</td>
<td>1210-E</td>
<td>718205</td>
<td>HUNTINGTON WB</td>
<td>On Ramp</td>
<td>4257</td>
<td>Appear permanently broken</td>
<td>Fixed - Shows all Green in PMs (9/30/16)</td>
</tr>
<tr>
<td>47</td>
<td>1210-E</td>
<td>761154</td>
<td>MYRTLE AV</td>
<td>Off Ramp</td>
<td>4259</td>
<td>Appear permanently broken</td>
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<tr>
<td>48</td>
<td>1210-E</td>
<td>761167</td>
<td>MOUNTAIN</td>
<td>Off Ramp</td>
<td>4260</td>
<td>Appear permanently broken</td>
<td>Off1 bit needs to be turned on (9/30/16)</td>
</tr>
</tbody>
</table>
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
Detector operational problems can significantly affect data produced by arterial sensors.

- Missing peak hour volume
- Unusual flow profiles
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)

- **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

![Map of Arcadia with different symbols indicating detector status]
Assessing Detector Health

Example: Weekly detector health status report for Arcadia

<table>
<thead>
<tr>
<th>Intersections</th>
<th>Detour Routes</th>
<th>System Detectors</th>
<th>Status</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>35</td>
<td>ON_LINE</td>
<td>407</td>
<td>434</td>
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<tr>
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<td>COMM_ERROR</td>
<td>23</td>
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<tr>
<td></td>
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<td>COMM_ERROR/ON_LINE</td>
<td>4</td>
<td></td>
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<tr>
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<td>65</td>
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<td>COMM_ERROR</td>
<td>76</td>
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<tr>
<td></td>
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<td>COMM_ERROR/ON_LINE</td>
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</tr>
<tr>
<td>No</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Criteria for "Good" detectors:
- Data missing rate <5%
- Data inconsistency rate <15% (e.g., occupancy =0, but volume =40)
- Not reporting zero values (Currently 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.
Assessing Detector Health

- Example: Weekly detection health summary for Arcadia

<table>
<thead>
<tr>
<th>Intersections</th>
<th>Detour Routes</th>
<th>System Detectors</th>
<th>Status</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>35</td>
<td>SN_LINE</td>
<td>407</td>
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<tr>
<td></td>
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<td>COMM_ERROR_LINE</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>16</td>
<td>SN_LINE</td>
<td>66</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>COMM_ERROR</td>
<td>76</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>COMM_ERROR_LINE</td>
<td>4</td>
</tr>
</tbody>
</table>
Data Factors – Data Variability

- Variability of arterial traffic flows

5-min Data

15-min Data
Data Factors – Flow-Occupancy Relationships

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

SCAG Tier 1
Traffic Analysis Zones (TAZ)
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

385 origin-destination centroids
- 8 → Boundary freeway connections
- 109 → Boundary arterial connections
- 268 → Internal sources and sinks
Modeling of Trip Origins and Destinations

- Labeling of centroids for I-210 Corridor

Freeway boundary → “f” + Freeway Number + Descriptor
Arterial boundary → “e” + Quadrant + Street Name
Internal sink/sources → “i” + City Code + Neighborhood / Street Name
Correspondence between centroids and traffic analysis zones
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
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

- **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
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

88% of traffic along “sightseeing” trips
Trip Cost Calculation

- Example: Route selection considering travel time and distance

Cost = Travel Time + 1.0 * Distance

0% of traffic along “sightseeing” trips

<table>
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<tr>
<th>Interval</th>
<th>Percentage</th>
<th>Volume</th>
<th>Flow</th>
<th>Cost</th>
<th>Distance</th>
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</table>
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**

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<th>Type</th>
<th>Formula</th>
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<tbody>
<tr>
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<tr>
<td>Freeways – Main lanes</td>
<td>Travel Time + 0.85 * Distance + Ramp Meter Penalty</td>
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<tr>
<td>Freeway - HOV lanes</td>
<td>Travel Time + 0.80 * Distance + Ramp Meter Penalty</td>
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</tbody>
</table>
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
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
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?