Coordination of Freeway Ramp Meters and Arterial Traffic Signals (FOT)

XY Lu, PATH, Project Manager and Principal Researcher
Dongyan Su, GSR, PATH, U. C. Berkeley

Project PI: Alex Skabardonis

01/30/2012
Outlines

• Project Objectives
• Task 1: Project Management Activities
• Task 2: Literature Review
• Task 3: Develop Work Plan and Finalizing the ConOps
• Task 4: Site Selection and Simulation Development
• Discussion and Comments
Project Objectives – Long Term

• Large scale system problem:
  – Freeway corridor traffic and control
  – Related arterial(s) intersections traffic and control
  – Dynamic interaction between the two

• To resolve any (or potential) inconsistency and conflict between the two traffic control systems;

• To balance the traffic flows overall system for accommodating more traffic in peak hours;

• To eventually minimize Total Travel Time (TTT) system wide and to improve mobility, reduce emission and energy consumption;
Project Objectives – Short Term

- To coordinate one (feeding) intersection and one onramp meter
- To identify
  - Where and when coordination is necessary
  - Where and when is feasible
  - Technical hurdles in coordination of the two subsystems
  - Conflict of interests between the two and how to resolve
- To hopefully improve the performance of the system in some aspect in some level which could be quantified;
- To set an example for overcoming any hurdle(s) caused by multiple jurisdictions;
- To laid down a good foundation for a large project involving a freeway corridor and related arterial corridor(s) if it is successful.
Task 1: Project Management Activities

• Worked together with Caltrans Project Manager to:
  – Finalize TAG Charter Document;
  – Finalize MOU document;
  – Attend the Kick-off meeting scheduled for October 6th in D4;
  – Submitted quarterly report
Task 2. Technical Literature Review

• Coordinated Ramp Metering;
• Coordinated Arterial Traffic Control Strategies;
• Coordinated Freeway Corridor Ramp Metering and Arterial Traffic Signal Control;
Coordinated Ramp Metering

- ALINEA-local traffic responsive;
- ALINEA/Q with onramp queue handling;
- FLOW - a coordinated algorithm that keeps the traffic at a predefined bottleneck below capacity;
- Linked Algorithm, which is a coordinated algorithm that seeks to optimize a linear quadratic objective function.


Coordinated Ramp Metering

- System Wide Adaptive Ramp Metering (SWARM) developed by National Engineering Technology (NET) Corporation. It is totally based on linear regression of measured data for prediction of density instead of model-based.


- Potential Problem:
  - is impossible to predict the traffic without a model
  - linear regression cannot capture traffic transition dynamics
  - difficult to achieve good performance for freeway traffic control
Coordinated Ramp Metering

• Recent implementation HERO project in Australia was claimed very successful;

• Essentially coordinated ALINEA;
• Coordination strategy: maximum use of onramp storage starting from downstream to upstream;
  – If onramps are too short, or onramp demands are too high, this approach may not have good performance

• Paper: V. Vong, Implementing Traffic Management Tools to Mitigate Freeway Congestion, CD ROM of 12th IFAC Symposium on Control in Transportation Systems, Redondo Beach, CA, USA, September 2 - 4, 2009
### Evaluation of Monash Freeway Inbound

Jacksons Rd to High St (6:00 AM to 9:00 AM)  
15 Kilometres – June 2008

<table>
<thead>
<tr>
<th>Performance Indicators</th>
<th>Values</th>
<th>Improvements*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fixed Time</td>
<td>HERO</td>
</tr>
<tr>
<td>Average Flow (pcu/h/lane)</td>
<td>1731</td>
<td>1816</td>
</tr>
<tr>
<td>Travel Speed (km/h)</td>
<td>48.9</td>
<td>66</td>
</tr>
<tr>
<td>Average Delay (min/km)</td>
<td>0.49</td>
<td>0.17</td>
</tr>
<tr>
<td>100% Productivity (%)</td>
<td>29.4</td>
<td>72.3</td>
</tr>
<tr>
<td>Less than 20% Speed Variation (%)</td>
<td>26.3</td>
<td>65.4</td>
</tr>
<tr>
<td>Grade One Reliability</td>
<td>22.4</td>
<td>40.8</td>
</tr>
</tbody>
</table>

*Note existing system also had ramp signals*
Benefits

- Flow at bottlenecks of 2166 pcu/h/lane (cf textbook 2200)
- Net saving of 4min 48 sec per vehicle over 15km section
- Equivalent to 1900 Veh.hrs of delay savings p/day
  - Equivalent in time of driving 190,000km (119,000 miles) at 100km/h each day
    
    (Driving from Los Angeles to New York 43 times)

- Saving of 16,500 litres of petrol a day
- Reduction in Greenhouse Gas of 40 tonne per day

- Reduction of casualty crashes by >30%

*Note: results are from road works conditions ie narrow lanes, no shoulders and 80km/h speed limits*
### Economic Benefits
Travel Time + Vehicle Operating Costs (VOC)

<table>
<thead>
<tr>
<th>Timeframe</th>
<th>Delay Reduction on Freeway (veh.h)</th>
<th>Extra Delay Ramps (veh.h)</th>
<th>Delay Reduction (veh.)</th>
<th>Saving</th>
<th>Total Saving per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>6:00 to 10:00 AM</td>
<td>169</td>
<td>38</td>
<td>1411</td>
<td>$40,323</td>
<td>$54,116</td>
</tr>
<tr>
<td>4:00 to 7:00 PM</td>
<td>30</td>
<td>483</td>
<td></td>
<td>$13,793</td>
<td>$39,501 VOC</td>
</tr>
</tbody>
</table>

Payback Period < 11 Days

Cost of Trial $1M

= $93,617
Coordinated Ramp Metering

- Lu et al (2010 - 2011) developed an algorithm for combined VSL and CRM for maximize bottleneck flow of freeway corridor;
- CRM can be implemented alone – the speed in model just use the estimated traffic speed from sensor measurement;
- Model based and it is linearized if speed is known;
- Objective function for optimal control: \( VHT - VMT \)
- Further simplified as Model Predictive Control ➔ linear programming (LP) problem in each time step
- The algorithm takes into account the following factor:
  - Demand variation at each onramp
  - Demand and capacity of the upstream links
  - Onramp storage capacity (queue length limit)
  - Onramp capacity flow
Coordinated Ramp Metering

Coordinated Ramp Metering

• Further thoughts on ramp metering
  – Onramp queue detection
  – Maximum onramp lane capacity flow under ramp metering (1-veh per green)
    ➢ ~1000 veh/hr?
    ➢ Any example?
  – Maximum onramp lane capacity flow under ramp metering (or 2 or more vehicles per green)
  – Quantitative relationship between metering rate and onramp flow considering vehicle stop and start delays
  – How to meter if two onramp lanes are to merge into one lane before merging into freeway
Coordinated Arterial Traffic Control

- Optimal coordination strategy
- Dynamic optimization algorithm for traffic signal control
- Control parameter as the outcome of the optimization:
  - cycle time
  - off-set
- Filed operational test

Coordinated Arterial Traffic Control

- Coordination strategy
  - Fixed time-of-day
  - Adaptive all the time
- Adaptively coordinated signals significantly improves traffic performance for the arterial through traffic compared to fixed-time control in all test sites;
- Benefits depend on the amount and utilization of the spare green time in the background cycle length
  - Green time redistribution at each intersection
  - Offset to accommodate such changes
- How to use such spare green time in large scale
Coordinated Arterial Traffic Control


Coordinated Arterial Traffic Control

- A good review of Adaptive Traffic Control Systems (ATCS)
  - SCATS (stop line detector)
  - SCOOT (upstream – far side detector)
  - LA ATC (upstream – mid-block detector)
  - Seven others
- Some level of adaptation to current traffic
  - responsive (control input based previous cycle traffic state)
  - proactive (technique to predict traffic demand from upstream measurement)

Coordinated Arterial Traffic Control

- The following aspects were reviewed:
  - Adaptive traffic control logistics
  - Detector requirement
  - Compatibility with NEMA local traffic control system
  - Computer processor, software, and communications required
  - Vendor’s opinions, user interface, user’s feedback
  - Cost and benefit: deployment situations and maintenance

- Critical parameters to be determined:
  - Cycle length
  - Green time distribution for each movement for each cycle
  - Offset along the corridor: benefit one direction or two?
  - Safety critical logistics unchanged unless phase sequence changed
Coordinated Arterial Traffic Control

• Further thoughts:
  – Larger demand in main movement needs longer cycle length and green time (larger flow):
    ➢ TOD directional demand along arterial corridor
    ➢ Priority of each movement at an intersection
    ➢ Turning ratios
    ➢ Onramp if freeway demand is high and congested

  – Capacity flow per lane under traffic control
    ➢ With queue
    ➢ Without queue
    ➢ Under proper offset
Coordinated Freeway Corridor RM and Arterial Traffic Signal Control

• Simulation study identified four high level strategies to integrate freeway RM and arterial signals:
  – Local coordination
  – Area wide RM and arterial coordination
  – Diversion in case of incident/accident/WZ
  – Coordination for congestion relief
• The purposes and functions for those coordination are different

Coordinated Freeway Corridor RM and Arterial Traffic Signal Control

• The following study evaluate the coordination of freeway adaptive local traffic responsive ramp metering and arterial adaptive interchange signal timing
• With diamond exchange only
• Simple and intuitive control strategy:
  – whenever a long queue is detected at onramp, the signal timing should be adjusted to reduce the traffic flow entering the ramp
  – Otherwise, faster feeding flow
• Claimed significant improvement in performance to minimize the possibilities of a freeway breakdown;

Coordinated Freeway Corridor RM and Arterial Traffic Signal Control

• A strategy to relieve the problem in onramp storage use caused by platoon feeding
• Strategy: two-level variable metering rate to reduce delay at a ramp meter signal
• For single intersection only

Coordinated Freeway Corridor RM and Arterial Traffic Signal Control

• The following paper identified several issues in the integration of freeway RM and arterial traffic control
  – technically integrating diverse technologies and systems from a variety of competing vendors into the same platform;
  – severe institutional limitations on programming, implementing, and operating ATMS technologies;
  – the lack of a systems approach for project planning and management of different vendors and stakeholders;
  – too ambitiously large scale implementation without sufficient understanding the functionality and performance of each subsystem;
  – Our opinion: Also need to understand in which aspects the coordination can improve traffic;
Coordinated Freeway Corridor RM and Arterial Traffic Signal Control

Coordinated Freeway Corridor RM and Arterial Traffic Signal Control

• In Part II of the following report: two numerical algorithms for coordination were proposed:
  – the global strategy aimed at optimizing corridor performance while taking into account all control elements and the traffic conditions throughout the corridor
  – Only time-of-day intersection traffic signal control was considered
  – Cycle length and phasing sequences are fixed
  – Very simple RM strategy
• Comment: Freeway adaptive RM does not match with TOD intersection traffic signal control
Coordinated Freeway Corridor RM and Arterial Traffic Signal Control

- Irvine team developed simulation for corridor level integration of Freeway RM and Arterial Intersection traffic control:
- Features:
  - Restricting control parameters manageable in 170 or 2070
  - Estimation intersection traffic and onramp storage left
  - Predict intersection arrivals from upstream
  - Total system delay taken into account
  - Decision parameters:
    - gap settings: upper and lower bounds
    - Maximum/minimum green settings
    - ramp meter headway settings: upper and lower bounds
    - all are bound setting, not the value within the bound ➔ basically still use the default signal control
Coordinated Freeway Corridor RM and Arterial Traffic Signal Control

- Comments:
  - FD diagram in RM strategy is not adaptive
  - There is no particular coordination for freeway RM along the corridor
  - Multi-objective minimization is not feasible mathematically unless they are combined into one objective function with proper weights
  - Beside upper/lower bounds for the following parameters, we could go further to determine the values within the bounds:
    - Cycle length
    - Green time distribution
    - Offset
  - As long as we do not touch the safety critical logistics such as phase sequence, safety requirement remains
Coordinated Freeway Corridor RM and Arterial Traffic Signal Control


Coordinated Freeway Corridor RM and Arterial Traffic Signal Control

• Further thoughts:
  – To quantify the relationship between cycle length, green time and traffic flow at intersection
  – How timing can achieve desired feeding flow to freeway without affecting cross street traffic
    – to achieve maximum feeding flow if freeway demand is not high
    – to balance storage use at each intersection and onramp if freeway demand is high and congested
  – Capacity flow per lane under traffic signal control
    ➢ With queue
    ➢ Without queue
    ➢ Under proper offset
Task 2. Develop Project Work Plan and Finalize ConOps

• Work Plan in VEE-Diagram
Task 2. Work Plan– High Level

1. Literature Review
2. Site selection
3. Coordination Strategy Development
4. Interface with Traffic Controller
5. System Integration
6. System Tuning
7. Limited Time Field Test
8. Microscopic Simulation for Selected Site
9. Data Accessing
10. Limited Time Field Test
11. Data Analysis for Evaluation
Task 2. ConOps – Low Level

Control Cabinet
- Traffic Controller
  - ATCS
- Offset
  - Cycle length
  - Green time
- Traffic detector
  or controller

PATH Computer
- Traffic signal
  control algorithm
- Traffic data
  processing
- GPRS modem

Local RM Cabinet
- Ramp metering
  controller
- Ramp metering rate
- Traffic data server

PATH Computer
- Ramp meter algorithm
- Coordination algorithm
- Traffic data
  processing
- GPRS modem
Task 3: Site Selection and Simulation Development

- Main Factors for Site Selection
- Review of Preliminary Site Selection Based on PeMS Data
- Two Site Visits:
  - October 17, 2011: SR87-Taylor SA and SR85-Camden NB
  - November 16, 2011:
    - SR85-Camden NB
    - SR87 SB crossing with West Heading ➔ Taylor ➔ Julian PM Peak

- Simulation Development for Two Candidate Site
  - SR87 Taylor SB
  - SR85 Camden NB
Task 4: Site Selection and Simulation Development

- Main Factors for Site Selection
- Review of Preliminary Site Selection with PeMS Data
  - Traffic at SR87-Taylor, SB
  - Traffic at SR85-Camden, NB
- Two Site Visits
- Simulation Development for Two Candidate Sites
Main Factors for Site Selection

- Recurrent congestion in a peak hour(s)
- System Isolation: To make sure that the congestion is mainly caused by the interaction of freeway and arterial traffic flow
  - Capacity of the subject section
  - Freeway demand upstream
  - Freeway demand downstream (not caused by back-propagation)
  - Traffic demand from current onramp (eventually from arterial)
  - Arterial intersection traffic signal control
- Onramp length and number of lanes (storage capacity)
- Sensor locations and density
- Data quality
- Complexity of the system
Review of Preliminary Site Selection with PeMS Data
Traffic at SR87-Taylor Downstream, SB
Road Geometry and Sensor of SR85-Camden
Traffic at SR85-Camden, NB

Raw Data for Poinline 400148 - All Lanes
LDS 402473: (Not Specified)
Mon 09/20/2010 00:00:00 to Wed 09/22/2010 23:55:59

Flow (veh/min)

09/20 09/20 09/20 09/20 09/21 09/21 09/21 09/21 06/22 06/22 06/22 06/22 06/22 12:00 18:00 00:00 06:00 12:00 18:00 00:00 06:00 12:00 18:00
00:00 05:00 10:00 15:00 20:00 25:00 00:00 05:00 10:00 15:00 20:00 25:00

400148 Lane 1 Flow 400148 Lane 2 Flow 400148 Lane 3 Flow
Traffic at SR85-Camden, NB

[Map of the area with a marker indicating the location for LDS 402473: (Not Specified)]

[Graph showing speed data for Mainline 400148 - All Lanes from Mon 05/20/2010 00:00:00 to Wed 09/22/2010 23:59:59]

- Speed (mph)
- Time (06:00 to 18:00 in 12-hour intervals)

Legend:
- 400148 Lane 1 Speed
- 400148 Lane 2 Speed
- 400148 Lane 3 Speed

[Logos for Caltrans and PATH]
Traffic at SR85-Camden, NB

Raw Data for Mainline 400148 - All Lanes
LDS 402473: (Not Specified)
Thu 09/23/2010 00:00:00 to Sat 09/25/2010 23:55:59

Flow (veh/3 min)

0 20 40 60 80 100 120 140 160 180 200
09/23 09/23 09/23 09/23 09/24 09/24 09/24 09/24 09/24 09/25 09/25 09/25 09/25 09/25 09/25
00:00 01:00 02:00 03:00 04:00 05:00 06:00 07:00 08:00 09:00 10:00 11:00 12:00 13:00 14:00
400148 Lane 1 Flow 400148 Lane 2 Flow 400148 Lane 3 Flow
Traffic at SR85-Camden Downstream, NB

Raw Data for Mainline 400700 - All Lanes
LDS 402475: (Not Specified)
Mon 09/20/2010 00:00:00 to Wed 09/22/2010 23:59:59

[Graph showing traffic flow over time]
Traffic at SR85-Camden Downstream, NB

Raw Data for Mainline 400700 - All Lanes
LDS 402475: (Not Specified)
Mon 09/20/2010 00:00:00 to Wed 09/22/2010 23:55:59

[Graph showing traffic data with speed on the y-axis and time on the x-axis, with three lines representing different lanes.]
Traffic at SR85-Camden Downstream, NB

LDS 402475: (Not Specified)

Current Location

Map data ©2011 Google

Raw Data for Mainline 400760 - All Lanes
LDS 402475: (Not Specified)
Mon 09/27/2010 00:00:00 to Wed 09/29/2010 23:59:59

Flow (veh/5 min)

0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200

00:00 06:00 12:00 18:00 00:00 06:00 12:00 18:00 00:00 06:00 12:00 18:00 00:00 06:00 12:00 18:00

400760 Lane 1 Flow 400760 Lane 2 Flow 400760 Lane 3 Flow

PATH
Traffic at SR85-Camden Downstream, NB

LDS 402475: (Not Specified)

Raw Data for Mainline 400700 - All Lanes
LDS 402475: (Not Specified)
Mon 09/27/2010 00:00:00 to Wed 09/29/2010 23:59:59

0 50 100 150 200 250
0 06:00 12:00 18:00 00:00 06:00 12:00 18:00 00:00 06:00 12:00 18:00 00:00
400700 Lane 1 Speed 400700 Lane 2 Speed 400700 Lane 3 Speed
<table>
<thead>
<tr>
<th>Site: I280-Saratoga</th>
<th></th>
<th>Site: SR87-Taylor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interested Directions</strong></td>
<td><strong>SB</strong></td>
<td><strong>NB</strong></td>
</tr>
<tr>
<td>Traffic demand upstream &amp; onramp (# veh/hour/lane)</td>
<td>Frwy</td>
<td>Arterial</td>
</tr>
<tr>
<td>AM</td>
<td>1500</td>
<td>1600</td>
</tr>
<tr>
<td>PM</td>
<td>1800</td>
<td>1200</td>
</tr>
<tr>
<td>Upstream off-ramp flow (# veh/hour/lane)</td>
<td>Frwy</td>
<td>Arterial</td>
</tr>
<tr>
<td>AM</td>
<td>N. A.</td>
<td>1535</td>
</tr>
<tr>
<td>PM</td>
<td>N. A.</td>
<td>970</td>
</tr>
<tr>
<td>Average Speed [mph]</td>
<td>Frwy</td>
<td>Arterial</td>
</tr>
<tr>
<td>AM</td>
<td>50-65</td>
<td>20</td>
</tr>
<tr>
<td>PM</td>
<td>25</td>
<td>65</td>
</tr>
<tr>
<td># of lanes</td>
<td>Frwy</td>
<td>Arterial</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Ramp lanes/length (storage capacity)</td>
<td>Frwy</td>
<td>Arterial</td>
</tr>
<tr>
<td>2 lanes/240m (74 veh)</td>
<td>2 lanes/352m (109 veh)</td>
<td>2 lanes/100m (31 veh)</td>
</tr>
<tr>
<td>Sensor location and density</td>
<td>Frwy</td>
<td>Arterial</td>
</tr>
<tr>
<td>1 LDS</td>
<td>1 LDS</td>
<td>1 LDS</td>
</tr>
<tr>
<td>Data quality</td>
<td>Frwy</td>
<td>Arterial</td>
</tr>
<tr>
<td>OK</td>
<td>OK</td>
<td>OK</td>
</tr>
<tr>
<td>Controller</td>
<td>Frwy</td>
<td>Arterial</td>
</tr>
<tr>
<td>2070</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System isolation</td>
<td>Frwy</td>
<td>Arterial</td>
</tr>
<tr>
<td>Difficult to isolate</td>
<td>Difficult to isolate</td>
<td>Some congestion Dwn</td>
</tr>
<tr>
<td>System complexity</td>
<td>Frwy</td>
<td>Arterial</td>
</tr>
<tr>
<td>complicated</td>
<td>complicated</td>
<td>complicated</td>
</tr>
<tr>
<td>Jurisdiction</td>
<td>Frwy</td>
<td>Arterial</td>
</tr>
<tr>
<td>Caltrans D4</td>
<td>San Jose City</td>
<td>Caltrans D4</td>
</tr>
<tr>
<td>Likelihood of some performance improvement in Phase I</td>
<td>Frwy</td>
<td>Arterial</td>
</tr>
<tr>
<td>Very difficult</td>
<td>Very difficult</td>
<td>possibly</td>
</tr>
<tr>
<td>Comments</td>
<td>Frwy</td>
<td>Arterial</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site</td>
<td>SR85-Camden</td>
<td>I280-Lawrence</td>
</tr>
<tr>
<td>-----------------</td>
<td>-------------</td>
<td>---------------</td>
</tr>
<tr>
<td><strong>Directions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frwy</td>
<td>Frwy</td>
<td>Frwy</td>
</tr>
<tr>
<td>Arterial</td>
<td>Arterial</td>
<td>Arterial</td>
</tr>
<tr>
<td><strong>Traffic demand</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>From upstream and arterial (#veh/hr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AM</td>
<td>1500</td>
<td>1700~1800</td>
</tr>
<tr>
<td>PM</td>
<td>1680</td>
<td>1200~1500</td>
</tr>
<tr>
<td><strong>Average Speed [mph]</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AM</td>
<td>65</td>
<td>15</td>
</tr>
<tr>
<td>PM</td>
<td><strong>40~60</strong></td>
<td>65</td>
</tr>
<tr>
<td><strong># Lanes</strong></td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td><strong>Ramp lanes/length</strong> (storage capacity)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 lanes 210m (65 veh)</td>
<td>2 lanes 115m (36 Veh)</td>
<td></td>
</tr>
<tr>
<td><strong>Sensor location and density</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Up onramp</td>
<td>1 Up onramp</td>
<td></td>
</tr>
<tr>
<td><strong>Data quality</strong></td>
<td>OK</td>
<td>OK</td>
</tr>
<tr>
<td><strong>Controller</strong></td>
<td>Isolated if data correct</td>
<td>Isolated if data correct</td>
</tr>
<tr>
<td><strong>System isolation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>System complexity</strong></td>
<td>simple</td>
<td>simple</td>
</tr>
<tr>
<td><strong>Jurisdiction</strong></td>
<td>Caltrans D4</td>
<td>Caltrans D4</td>
</tr>
<tr>
<td></td>
<td>San Jose city</td>
<td>San Jose city</td>
</tr>
<tr>
<td><strong>Likelihood of some performance improvement in Phase I</strong></td>
<td>Unlikely</td>
<td>Possibly</td>
</tr>
<tr>
<td><strong>Comments</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Terminologies

• Storage capacity: **250 vehicles per mile per lane assumed**;

• **Isolated:** Congestion is unlikely to be caused by traffic from congestion downstream back-propagation; or off-ramp spills back.
Two Site Visits

- **October 17, 2011:** SR87-Taylor SA and SR85-Camden NB
  - To observe traffic
  - To talk to traffic and electrical engineers of San Jose Transportation

- **November 16, 2011:**
  - SR85-Camden NB
  - SR87 SB crossing with West Heading ➔ Taylor ➔ Julian  PM Peak
Simulation Development for Two Candidate Sites

- SR87 Taylor SB
- SR85 Camden NB
SR87 & W Taylor St

- **Road Geometry:**
  - From W Taylor St to W Julian St
  - 1.8 km
  - 2 directions of freeway
  - 4 on-ramps, 3 off-ramps

- **Control:**
  - Intersection: Actuated control, timing plan from D4
  - Metering rate: from a 15min video, took at 5:00pm, Jan 18, 2012, Wed.

- **Demand**
  - Intersection flow and ramp flow at W Taylor St: from a 15min video, took at 4:30pm, Jan 18, 2012
  - Julian ramps flow: unknown, set to 500 vph
  - Freeway mainline flow: SB 3200 vph, NB 2000 vph estimated from PeMS
  - Vehicle types: 80% GP Lane, 20% HOV Lane (estimated by the 15min video at Taylor St onramp)
SR85N & Camden Ave

• Road Geometry:
  – From Camden Ave to Union Ave
  – 3.9 km
  – 1 direction, NB
  – 2 on-ramps, 2 off-ramps

• Control:
  – Intersection: Actuated control, timing plan from City of San Jose
  – Metering rate: unknown, set to 1100 vph

• Demand
  – Intersection flow and ramp flow at Camden Ave: 7:45am-8:45am data collected in 2008, from City of San Jose
  – Union ramps flow: set to 500 vph
  – Freeway mainline flow: 4500 vph
  – Vehicle types: 80% GP Lane, 20% HOV Lane
Discussion and Comments