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

XY Lu
PATH, Project Manager and Principal Researcher

Project PI: Alex Skabardonis
10/06/2011
Outlines

- Project Objectives
- Concept of Operation
- Site Selection Considerations
- 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.
Concept of Operation – High Level

1. Literature Review
2. Coordination Strategy Development
3. Interface with Traffic Controller
4. System Integration
5. System Tuning
6. Limited Time Field Test
7. Microscopic Simulation for Selected Site
8. Data Accessing
9. Data Analysis for Evaluation
Concept of Operation – 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

Interface

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

PATH Computer
- Ramp meter algorithm
- Coordination algorithm
- Traffic data processing
- GPRS modem

Interface

6
Site Selection Considerations

• Main Factors for Site Selection
• Data Analysis for Site Selection
• Summary of Site Selection
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
Data Analysis for Site Selection

- Five sites considered, but concentrated on first three
  - I280-Saratoga
  - SR87-Taylor
  - SR85-Camden
  - I280-Lawrence
  - SR101-DeLaCruz
Road Geometry at I280-Saratoga
Road Geometry and Sensor of I280-Saratoga, SB
I280-Saratoga, SB Traffic Pattern

Raw Data for Mainline 400292 - All Lanes
Mainline VDS 400292 - Saratoga ave rm-s-diag
Mon 09/20/2021 06:00:00 to Wed 09/22/2021 23:59:59

Flow (Veh/5 min.)
I280-Saratoga, SB Traffic Pattern
I280-Saratoga, SB Traffic Pattern

[Map and diagram showing traffic pattern]
I280-Saratoga, SB Traffic Pattern

**Mainline VDS 400292 - Saratoga ave rm-s-diag**

- Map data ©2011 Google

**Row Data for Mainline 400292 - All Lanes**
- Mainline VDS 400292 - Saratoga ave rm-s-diag
- Thu 09/23/2010 00:00:00 to Sat 09/25/2010 23:55:59

**Graph**
- Speed (mph)
- Time (09/23 00:00:00 to 09/25 23:55:59)

**Legend**
- 400292 Lane 1 Speed
- 400292 Lane 2 Speed
- 400292 Lane 3 Speed
- 400292 Lane 4 Speed

**Stations**
- CB ON FR HOLFE
- CB ON FR LAUDEN
- CB OFF TO MOUNTAIN
- CB OFF TO MOORE
I280-Saratoga Downstream, SB Traffic Pattern

Mainline VDS 401177 - 400' S of I7/880 IC

Raw Data for Mainline 401177 - All Lanes
Mainline VDS 401177 - 400' S of I7/880 IC
Mon 09/20/2010 00:00:00 to Wed 09/22/2010 23:55:59

Flow (veh/3 min)

9:30 AM 6:30 PM 7:30 AM 6:30 PM 5:30 PM 4:30 PM

401177 Lane 1 Flow 401177 Lane 3 Flow 401177 Lane 5 Flow 401177 Lane 7 Flow
401177 Lane 2 Flow 401177 Lane 4 Flow 401177 Lane 6 Flow

SS ON FF LAUREN SS ON FIRE RIGA SB FF TO WINCHE SS OFF TO MORGAN
I280-Saratoga Downstream, SB Traffic Pattern

Mainline VDS 401177 - 400' S of 17/880 IC

Raw Data for Mainline 401177 - All Lanes
Mainline VDS 401177 - 400' S of 17/880 IC
Mon 09/20/2010 00:00:00 to Wed 09/22/2010 23:59:59

Speed (mph)

0 20 40 60 80 100 120 140 160
06:00 06:30 07:00 07:30 08:00 08:30 09:00 09:30 10:00 10:30 11:00 11:30 12:00 12:30 13:00

401177 Lane 1 Speed
401177 Lane 2 Speed
401177 Lane 3 Speed
401177 Lane 4 Speed
401177 Lane 5 Speed
401177 Lane 6 Speed

SS ON FR LAUREN
SS ON FRM SARA
STAFF TO WINCHE
SS OFF TO MORG
Road Geometry and Sensor of I280-Saratoga, NB
I280-Saratoga, NB Traffic Pattern

Mainline VDS 400414 - Saratoga ave rm-n-diag

Flow Data for Mainline 400414 - All Lanes
Mainline VDS 400414 - Saratoga ave rm-n-diag
Mon 09/20/2010 00:00:00 to Wed 09/22/2010 23:59:59

Flow (Veh/30 sec) Flow (Veh/min)

0 50 100 150 200 250
09/20 09/20 09/20 09/20 09/21 09/21 09/21 09/21 09/22 09/22 09/22 09/22 09/22 09/22
00:00 05:00 10:00 15:00 00:00 05:00 10:00 15:00 00:00 05:00 10:00 15:00

400414 Lane 1 Flow 400414 Lane 2 Flow 400414 Lane 3 Flow 400414 Lane 4 Flow

NB OFF TO SE RT NB ON FR SE RTE NB OFF TO COAST NB OFF TO LAUREN NB OFF TO WOLF

4.97 5.97 6.97 7.97 0.97 9.97
I280-Saratoga, NB Traffic Pattern
I280-Saratoga, NB Traffic Pattern

![Map of I280-Saratoga, NB Traffic Pattern](image)

**Line VDS 400414 - Saratoga Ave RM-N-Dia**

**Row Data for Mainline 400414 - All Lanes**
Mainline VDS 400414 - Saratoga Ave rm-n-dia
Thu 09/23/2010 00:00:00 to Sat 09/25/2010 23:59:59

![Graph of I280-Saratoga, NB Traffic Pattern](image)
I280-Saratoga Downstream, NB Traffic Pattern

Raw Data for Mainline 400560 - All Lanes
Mainline VDS 400560 - Stevens Creek Blvd rm-
Mon 09/20/2010 00:00:00 to Wed 09/22/2010 23:59:59

Speed (mph)
0 50 100
09/20 09/20 09/20 09/20 09/20 09/20 09/20 09/20
00:00 06:00 12:00 18:00 00:00 06:00 12:00 18:00

400560 Lane 1 Speed
400560 Lane 2 Speed
400560 Lane 3 Speed
400560 Lane 4 Speed

NB OFF TO CALENT
NB OFF TO LOUSE
NB OFF TO WILFE
NB OFF TO BE GN
Mainline VDS 400560 - Stevens Creek Blvd rm-

Raw Data for Mainline 400560 - All Lanes
Mainline VDS 400560 - Stevens Creek Blvd rm-
Thu 05/23/2019 06:00:00 to Sat 09/28/2019 23:59:59

400560 Lane 1 Speed
400560 Lane 2 Speed
400560 Lane 3 Speed
400560 Lane 4 Speed

NB OFF TO COHRAT
WB OFF TO LUNAER
NB OFF TO WILFFE
NB OFF TO BE ON

5.51 7.51 9.51 9.51 10.51 12.51
Road Geometry and Sensor of SR87-Taylor
Traffic at SR87-Taylor, SB

Mainline VDS 402117 - Taylor Street rm-s-diag

Current Location

Raw Data For Mainline 402117 - All Lanes
Mainline VDS 402117 - Taylor Street rm-s-diag
Tue 06/08/2010 00:00:00 to Thu 06/10/2010 23:59:59

Flow (veh/min)

402117 Lane 1 Flow 402117 Lane 2 Flow 402117 Lane 2 Speed

Flow

0 20 40 60 80 100

06/08 06/08 06/08 06/08 06/09 06/09 06/09 06/10 05/10 05/10
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 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00

0 60 120 180

Speed (mph)

0 20 40 60 80 100

06/08 06/09 06/09 06/09 06/09 06/09 05/10 05/10
00:00 01:00 02:00 03:00 04:00 05:00 06:00 07:00

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

0 5 10 15 20 25 30

06/08 06/09 06/09 06/09 06/09 06/09 05/10 05/10
00:00 01:00 02:00 03:00 04:00 05:00 06:00 07:00

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

0 8.20 7.20 5.20 5.20 4.20
Traffic at SR87-Taylor, SB
Traffic at SR87-Taylor, SB

Raw Data for Mainline 402117 - All Lanes
Mainline VDS 402117 - Taylor Street rm-s-diag
Wed 06/23/2010 00:00:00 to Fri 06/25/2010 23:59:59

[Graph showing traffic flow and speed over time]
Traffic at SR87-Taylor Downstream, SB
Traffic at SR87-Taylor Downstream, SB
Traffic at SR87-Taylor Downstream, SB
Traffic at SR87-Taylor Downstream, SB
Traffic at SR87-Taylor, NB
Traffic at SR87-Taylor, NB
Traffic at SR87-Taylor, NB
Traffic at SR87-Taylor, NB
Traffic at SR87-Taylor, NB
Traffic at SR87-Taylor, NB
Traffic at SR87-Taylor, NB

[Map of San Jose with a red marker indicating the location of SR87-Taylor]

[Graph showing traffic flow with peaks at certain times]

44
Traffic at SR87-Taylor, NB
Road Geometry and Sensor of SR85-Camden
Traffic at SR85-Camden, SB

Raw Data for Mainline 400059 - All Lanes
LDS 402472: (Not Specified)
Mon 09/20/2010 00:00:00 to Wed 09/22/2010 23:55:59

Map data ©2011 Google
Traffic at SR85-Camden, SB

Current Location

Raw Data For Mainline 400009 - All Lanes
LDS 402472: (Not Specified)
Mon 09/20/2010 00:00:00 to Wed 09/22/2010 23:55:59
Traffic at SR85-Camden, SB
Traffic at SR85-Camden, SB
Traffic at SR85-Camden, SB
Traffic at SR85-Camden, SB

Raw Data for Mainline 400059 - All Lanes
LDS 402472: (Not Specified)
Mon 09/27/2010 00:00:00 to Wed 09/29/2010 23:59:59

400059 Lane 1 Speed  
400059 Lane 2 Speed  
400059 Lane 3 Speed  

Map data ©2011 Google
Traffic at SR85-Camden, NB

[Map of Camden and SR85]

[Graph showing traffic flow over time for all lanes at SR85-Camden]
Traffic at SR85-Camden, NB

LDS 402473: (Not Specified)

Map data ©2011 Google

Raw Data for Mainline 400148 - All Lanes
LDS 402473: (Not Specified)
Mon 06/20/2010 00:00:00 to Wed 09/22/2010 23:59:59

400148 Lane 1 Speed
400148 Lane 2 Speed
400148 Lane 3 Speed
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)

09/23 09/23 09/23 09/24 09/24 09/24 09/24 09/25 09/25 09/25 09/25 09/25
00:00 06:00 12:00 18:00 00:00 06:00 12:00 18:00 00:00 06:00 12:00 18:00

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

LDS 402475: (Not Specified)

Current Location

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

Flow (veh/5 min)

0 50 100 150 200 250
09/20 09/20 09/20 09/20 09/20 09/20 09/20
00:00 06:00 12:00 18:00 00:00 06:00 12:00

400700 Lane 1 Flow 400700 Lane 2 Flow 400700 Lane 3 Flow

Map data ©2011 Google
Traffic at SR85-Camden Downstream, NB

LDS 402475: (Not Specified)

Current Location

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

0 20 40 60 80 100 120 140 160 180 200

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

400700 Lane 1 Speed 400700 Lane 2 Speed 400700 Lane 3 Speed

Google Map data ©2011 Google
Traffic at SR85-Camden Downstream, NB

LDS 402475: (Not Specified)

Current Location

Raw Data for Mainline 400700 - All Lanes
LDS 402475: (Not Specified)
Thu 09/23/2010 00:00:00 to Sat 09/25/2010 23:59:59

Flow (veh/h

400700 Lane 1 Flow  400700 Lane 2 Flow  400700 Lane 3 Flow
Traffic at SR85-Camden Downstream, NB

Raw Data for Mainline 400700 - All Lanes
LDS 402475: (Not Specified)
Thu 09/23/2010 00:16:00 to Sat 09/25/2010 23:55:59

400700 Lane 1 Speed 400700 Lane 2 Speed 400700 Lane 3 Speed
Traffic at SR85-Camden Downstream, NB

LDS 402475: (Not Specified)

Current Location

Row 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)

09/27 00:00 09/27 06:00 09/27 12:00 09/27 18:00 09/28 00:00 09/28 06:00 09/28 12:00 09/28 18:00 09/29 00:00 09/29 06:00 09/29 12:00 09/29 18:00

400760 Lane 1 Flow  400760 Lane 2 Flow  400760 Lane 3 Flow
Traffic at SR85-Camden Downstream, NB
<table>
<thead>
<tr>
<th>Site</th>
<th>I280-Saratoga</th>
<th>SR87-Taylor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interested Directions</strong></td>
<td>Frwy Arterial Frwy Arterial Frwy Arterial Frwy Arterial</td>
<td>Frwy Arterial Frwy Arterial Frwy Arterial Frwy Arterial</td>
</tr>
<tr>
<td>Traffic demand upstream &amp; onramp (# veh/hour/lane)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AM</td>
<td>1500 1600</td>
<td>1800 1000</td>
</tr>
<tr>
<td>PM</td>
<td>1800 1200</td>
<td>1650 750</td>
</tr>
<tr>
<td>Upstream off-ramp flow (# veh/hour/lane)</td>
<td></td>
<td></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></td>
<td></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>4</td>
<td>4</td>
</tr>
<tr>
<td>Ramp lanes/length (storage capacity)</td>
<td>2 lane/240m (74 veh)</td>
<td>2 lanes/352m (109 veh)</td>
</tr>
<tr>
<td>Sensor location and density</td>
<td>1 LDS</td>
<td>1 LDS</td>
</tr>
<tr>
<td>Data quality</td>
<td>OK OK OK OK</td>
<td>OK 08/11 better than 09/11 OK OK 08/11 better than 09/11 OK OK</td>
</tr>
<tr>
<td>Controller</td>
<td>2070</td>
<td></td>
</tr>
<tr>
<td>System isolation</td>
<td>Difficult to isolate Difficult to isolate Some congestion Dwn No sensor Dwn</td>
<td></td>
</tr>
<tr>
<td>System complexity</td>
<td>complicated complicated complicated complicated simple simple simple simple</td>
<td></td>
</tr>
<tr>
<td>Jurisdiction</td>
<td>Caltrans D4 San Jose City Caltrans D4 San Jose City Caltrans D4 Caltrans D4 Caltrans D4 Caltrans D4</td>
<td></td>
</tr>
<tr>
<td>Likelihood of some performance improvement in Phase I</td>
<td>Very difficult Very difficult possibly possibly</td>
<td></td>
</tr>
<tr>
<td>Comments</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>Directions</td>
<td>SB Frwy Arterial</td>
<td>NB Frwy Arterial</td>
</tr>
<tr>
<td></td>
<td>AM 1500 604</td>
<td>AM 1700~1800 1024</td>
</tr>
<tr>
<td></td>
<td>PM 1680 845</td>
<td>PM 1200~1500 969</td>
</tr>
<tr>
<td>Traffic demand</td>
<td>From upstream and arterial</td>
<td>From arterial</td>
</tr>
<tr>
<td>AM</td>
<td>(#veh/hr)</td>
<td>(#veh/hr)</td>
</tr>
<tr>
<td>AM</td>
<td>AM 1500 604</td>
<td>AM 1700~1800 1024</td>
</tr>
<tr>
<td></td>
<td>PM 1680 845</td>
<td>PM 1200~1500 969</td>
</tr>
<tr>
<td>Average Speed [mph]</td>
<td>AM 65</td>
<td>AM 15</td>
</tr>
<tr>
<td></td>
<td>PM 40~60</td>
<td>PM 65</td>
</tr>
<tr>
<td># Lanes</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Ramp lanes/length</td>
<td>2 lanes 210m (65 veh)</td>
<td>2 lanes 115m (36 Veh)</td>
</tr>
<tr>
<td>(storage capacity)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensor location</td>
<td>1 Up onramp</td>
<td>1 Up onramp</td>
</tr>
<tr>
<td>and density</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data quality</td>
<td>OK</td>
<td>OK</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Controller</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System isolation</td>
<td>Isolated if data correct</td>
<td>Isolated if data correct</td>
</tr>
<tr>
<td>System complexity</td>
<td>simple</td>
<td>simple</td>
</tr>
<tr>
<td>Jurisdiction</td>
<td>Caltrans D4 San Jose city</td>
<td>Caltrans D4 San Jose city</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Likelihood of some</td>
<td>Unlikely</td>
<td>Possibly</td>
</tr>
<tr>
<td>performance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>improvement in Phase I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comments</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
• 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.
Discussion and Comments