Control Strategies for Corridor Management
Agreement 65A0329 TO008
Quarterly Progress Report (Fourth Quarter FY 2014-15) Version 1
Reporting Period: April 1st 2015 to June 30, 2015.

Brief Project Description

Considerable attention has been given to new approaches for improving the transportation system because of limited funding and environmental concerns for constructing new highway facilities. One promising approach is integrated management of travel corridors comprising of freeways and adjacent arterial streets controlled by traffic signals. However, the implementation and effectiveness of corridor management strategies is limited because of the lack of information on traffic conditions on arterials. Recently the availability of High-resolution (HR) data at signalized intersections consisting of time-stamped records of every event involving vehicles, together with the signal phase provides significant opportunities for assessing the performance of existing control and developing new control strategies. We propose to analyze real-time and archived HR data from three real-world test sites and calculate performance measures. We will next utilize the HR data to develop improved control strategies for arterials, and to propose and test corridor management control strategies for both recurrent and non-recurrent (incident related) congestion.

Work Completed This Quarter

The contract was executed in late March 2015. Authorization to proceed was received on April 2, 2015. The kick-off meeting for the project took place on June 11, 2015 at the Caltrans Division of Research & Innovation and Systems Information (DRISI) offices n Sacramento.

This quarter the following activities were performed:

Task 1. High Resolution Data Collection and Estimation of Performance Measures

Task 1 of the project is concerned with the collection and analysis of HR data at signalized intersections, and the calculation of performance measures. We have access to three sites with multilane and multiphase signals in Danville, California, Santa Clarita, California and Beaumont, South Carolina. The three study sites cover a wide range of operating conditions. The HR data is being collected in a server managed by Sensys Networks, Inc, in Berkeley, via a cellular modem. Data from the Danville site is available since October 2012; data from the other two sites is available beginning March 2014.

We accessed a sample of data and calculated a number of performance measures, e.g., the volume/capacity (V/C) ratio for each movement. The V/C ratio is equal to NC/(G ×S) where N is the vehicle count, G is the green time, S is saturation flow rate and C is the cycle length. The v/c ratios are used to determine the level of congestion for any particular movement, as linked to the level of service (LOS), with A being the best and F is worst.

Task 2. Development and Testing of Signal Control Strategies

The scope of work in Task 2 involves the development and evaluation of signal control

algorithms on signalized arterials. We will extend and refine the "max pressure" algorithm and simulate its performance using a mesoscopic simulation model called .Q. Both the control algorithm and the simulation model were developed at UC Berkeley.

This period we investigated possible real-world test beds to evaluate the performance of control algorithms with the .Q model. We identified three sites: El Camino Real in San Mateo, San Pablo Avenue in Berkeley and Huntington Avenue in Pasadena.

Meetings/Presentations

The project kick-off meeting was held at the Caltrans DRISI offices on June 11, 2015. The meeting participants and their contact information are listed below:

Participants	Organization	Phone	E-mail
Nicholas Compin	CT /Traffic OPS	(916) 651-1247	nicholas.compin@dot.ca.gov
Rex Cluff	CT/Traffic OPS	(916) 651-9059	rex.cluff@dot.ca.gov
David Wells	CT/Traffic OPS	(916) 227-4655	david.j.wells@dot.ca.gov
Shannon Culberson	CT/Traffic OPS	916-654-2701	shannon.culbertson@dot.ca.gov
Hamid Zolfaghari	CT/Traffic OPS	(916) 227-4662	hamid.zolfaghari@dot.ca.gov
Mike Jenkinson	CT/Traffic OPS	(916) 654-6912	mike.jenkinson@dot.ca.gov
Khanh Vu	CT/Traffic OPS	(916) 654-7139	khanh.vu@dot.ca.gov
Brian Simi	CT/Traffic Ops	916-654-3781	brian.simi@dot.ca.gov
Gurprit Hansra	CT/DRISI	(916) 654-7252	gurprit.hansra@dot.ca.gov
Jose Perez	CT/DRISI	(916) 654-9390	jose.d.perez@dot.ca.gov
Alexander Skabardonis	UCB/PATH	(213) 740-0670	dromeas@berkeley.edu

The project team presented the project objectives, expected products and ongoing and future work. Discussions focused on the results to-date, relationship of the research with other Caltrans projects, and next steps of the project.

Appendix A includes the presentation at the meeting by the research team.

Work Planned Next Quarter

Task 1. High Resolution Data Collection and Estimation of Performance Measures

We will continue the data acquisition and calculation of performance measures from the sites with the HR data. In cooperation with Sensys we will produce a database with HR data to be made available to the research community following the completion of the project.

Task 2. Development and Testing of Signal Control Strategies

We will apply the .Q model to a selected test site and assess its strengths and limitations in simulation analyses. We will extend the "max pressure" and evaluate its effectiveness in

improving the performance at the selected signalized arterial as compared to the modeling tools used by Caltrans (SYNCHRO software).

Problems/Issues Encountered This Quarter

There are no problems to report.

Project Budget Summary

The award amount is $114,222 for agreement number 65A0529 TO008. The agreement ends on February 29, 2016.

Projected expenditures for the fourth Quarter of FY 14/14 covering the months of April, May and June 2015 are shown below. These are draft estimates and will be refined when the financial statements will be made available by the University.

Month	Projected Expenditure ($)
April	0,000
May	4,000
June	5,000

Project Management References

Jose Perez
California Department of Transportation
Division of Research Innovation & Systems Information
1227 “O” Street, MS-83, Fifth Floor
Sacramento, CA 95814
P: (916) 654-9390
jose.d.perez@dot.ca.gov

Alexander Skabardonis, Principal Investigator
University of California, Berkeley
109 McLaughlin Hall
Richmond, CA 94720-1720
P: (510) 642-9166
skabardonis@ce.berkeley.edu

Appendix A.

Presentation at the Kick-off Meeting – June 11, 2015.

Caltrans Division of Research, Innovation & Systems Information

Agreement 65A0529

Control Strategies for Corridor Management

Alex Skabardonis

UC Berkeley

Project Kick-Off Meeting
Sacramento, CA
May 19, 2015

Project Objectives / Expected Results

- **Collect and Analyze High Resolution (HR) at traffic signals to calculate performance measures**
- **Develop and Test Improved Control Strategies for Signalized Arterials**
- **Propose and Test Freeway-Arterial Coordination Strategies**

- **A Database of HR data**
- **Methodology for estimating performance measures**
- **Analysis Tools & Control Strategies for Traffic Signals**
- **Freeway/Arterial Coordination Strategies**

Relation with Other Ongoing Studies

- **Development of an Adaptive Algorithm for Arterial Control**
  - HR data
  - Simulation testbed
- **Connected Corridors**
  - Control Strategy
  - Simulation Tool
  - Simulation testbed
- **Coordination of Freeway Ramp Meters and Arterial Traffic Signals**
  - Control algorithm for recurrent congestion

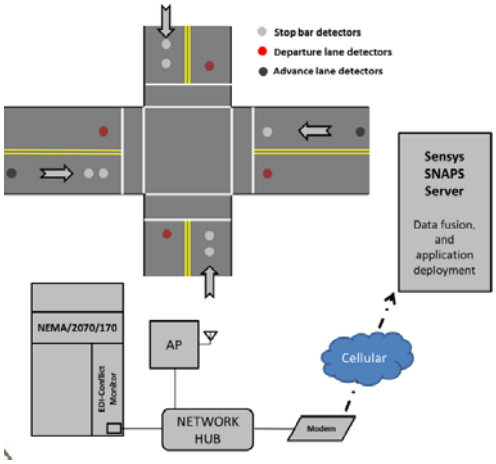
Sensys Networks—HR data

Collection of High Relation (HR) Data at Traffic Signals

- **Traffic data**
  - Detector data for each movement
    - stop bar detectors
    - advance detectors
    - detectors on departure lanes
- **Signal data**
  - Phase & Timing
- **Test Sites**

  All multiphase traffic signals
  - Danville, CA
  - Santa Clarita, CA
  - Beaumont, SC

Example: HR Data Collection Set-up

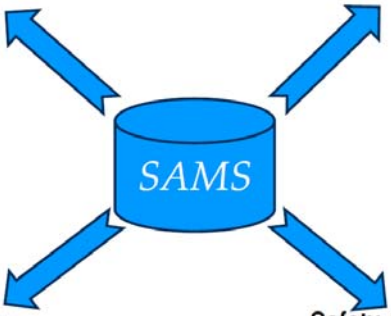


Danville Intersection

HR Data: Performance Measures

Capacity Analysis
Lane counts, Green Times, V-C ratios, LOS measures, Pedestrian calls

Progression/Delay Analysis
Percentage arrival on green, Average wait times

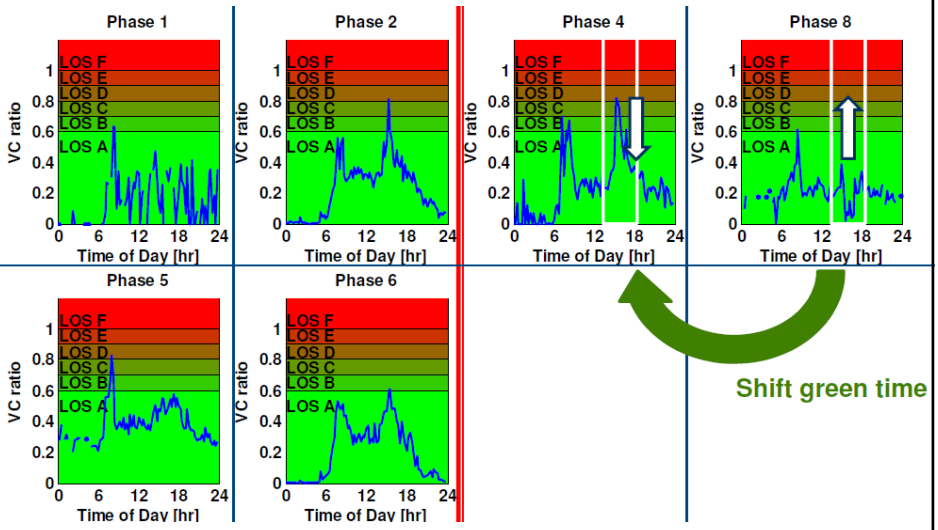


Side Street Analysis
Max wait times, wasted green

Safety Analysis
Red light violators, yellow light behavior, pedestrian obstruction.

SAMS: Safety and Mobility System

Analysis: Trade-offs between Signal Phases based on V/C



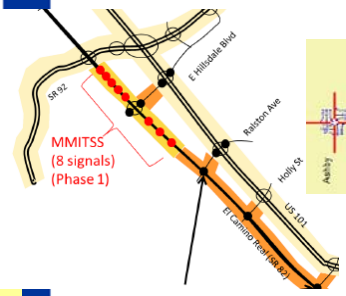
15 min V/C and LOS

Development and Testing of Signal Control Strategies based on HR Data

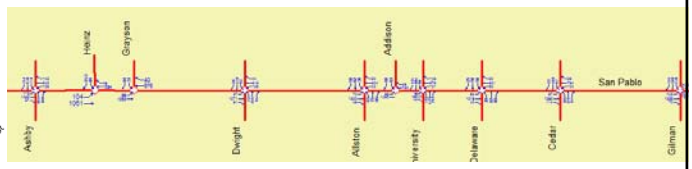
- **Control Algorithm**
  - "Max Pressure" algorithm
    - Distribution of green times based on the size of conflicting queues
  - Extend and refine the algorithm
- **Evaluation**
  - .Q model
    - Individual vehicles
    - Macroscopic modeling of traffic dynamics

Candidate Test Sites

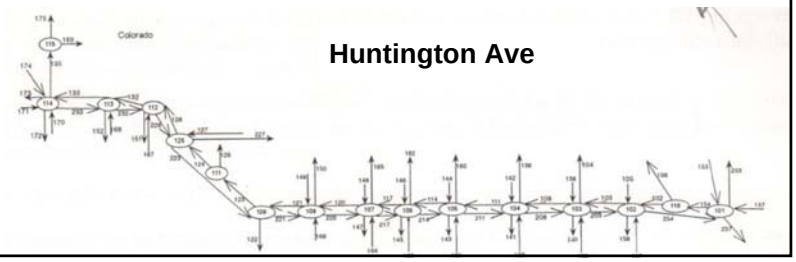
El Camino Real



San Pablo Ave



Huntington Ave

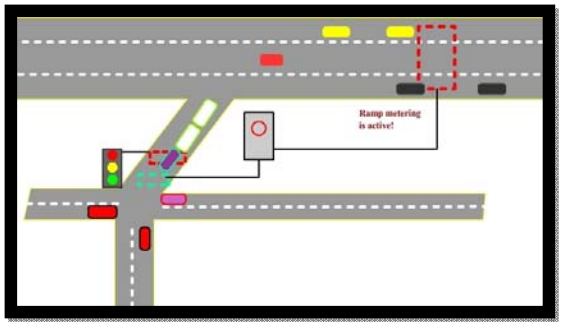


Freeway – Arterial Coordination

- **High Interest in Corridor Operations. Federal ICM and California CSMP**
- **Existing coordination guidelines mostly address institutional issues**
- **Most approaches (ICM) consist of "flush" signal timing plans on arterial in case of freeway incidents**
- **No field test results**

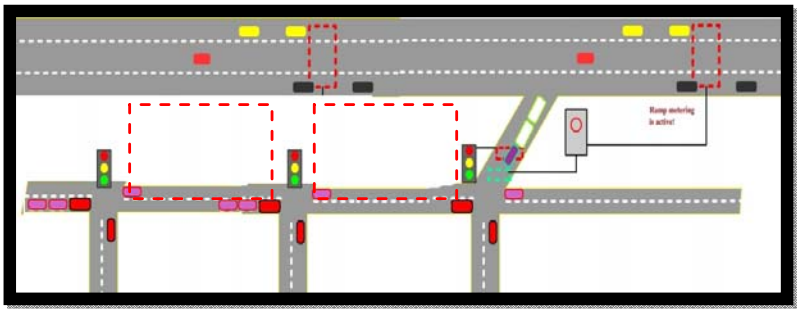
Control Strategies: Recurrent Congestion (1)

- **On-ramp access control:**
  reduces green times for signal phase(s) serving the on-ramp direction to avoid queue spillover from ramp metering



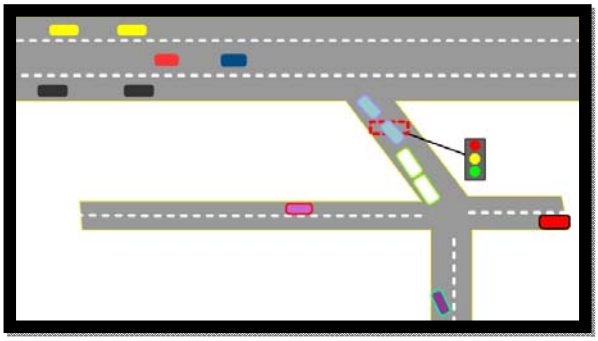
Control Strategies: Recurrent Congestion (2)

- **Equity Offset:**
  Use a sequence of surface street junctions leading to the on-ramp as additional storage space for the potential queue by altering signal offsets
  Extension of on ramp access control.



Control Strategies: Recurrent Congestion (3)

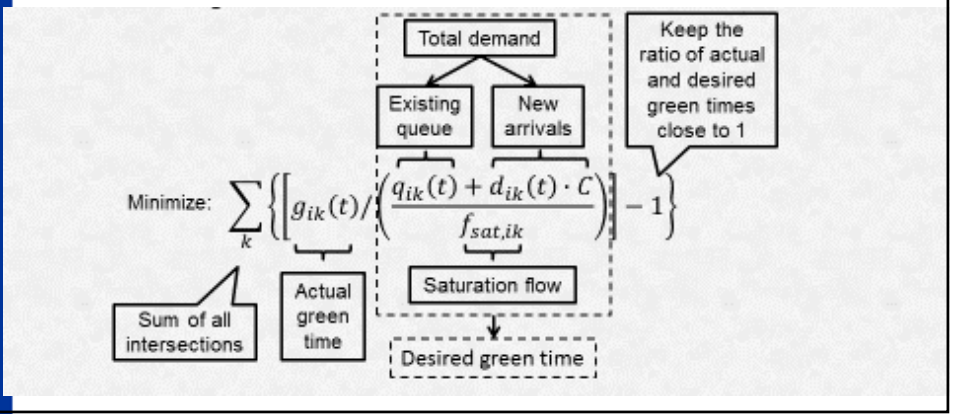
- **Off-ramp priority:**
  change signal settings at the off-ramp terminal based on the level of congestion measured by freeway loop detectors to avoid spillback on the freeway



Example Control Strategy (1)

Arterial with k intersections
Each intersection has i phases
Desired green time = minimum green time to serve the demand

Arterial: Minimize the ratio of actual and desired green times



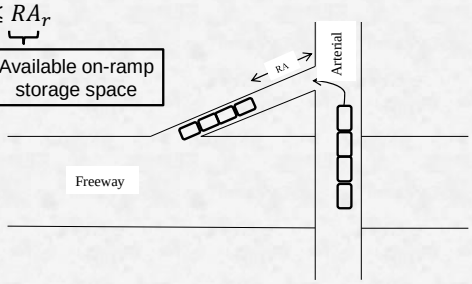
Example Control Strategy (2)

Constraints

- Minimum green time constraint: $g_{ik}(t) \geq G_{ik,min}$
- Cycle length constraint: $\sum_i g_{ik}(t) = C$
- On-ramp storage constraint:

$$\underbrace{\sum_{i \in R} f_{sat,ik} \cdot g_{ik}(t)}_{\text{Phases for on-ramp access}} \leq \underbrace{RA_r}_{\text{Available on-ramp storage space}}$$

Total flow onto freeway on-ramp

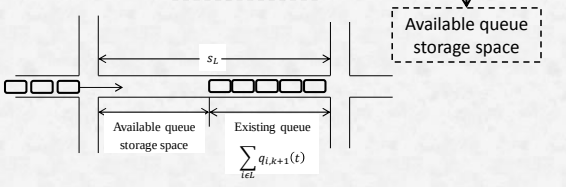


Example Control Strategy (3)

Constraint: Arterial link storage

$$\underbrace{f_{sat,ik} \cdot [\underbrace{o_{ik}(t)}_{\text{Offset}} + \underbrace{l_{acc}}_{\text{Lost time}}]}_{\text{Flow into downstream link}} \leq \underbrace{\left(s_L - \underbrace{\sum_{i \in L} q_{i,k+1}(t)}_{\text{Downstream queue length}}\right)}_{\text{Available queue storage space}}$$

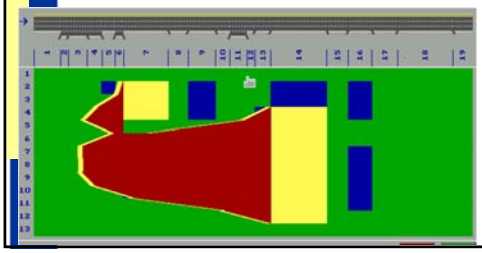
Link length



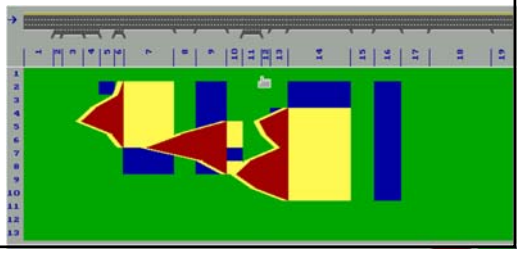
Control Strategies: Non-Recurrent Congestion

- **Key Issues:**
  - Freeway Operating conditions (congestion level)
  - Incident characteristics (location, severity)
  - Characteristics of freeway control & freeway surveillance
  - Characteristics of traveler information system
  - Characteristics of parallel arterial(s)

Incident at Bottleneck



Incident Upstream of Bottleneck

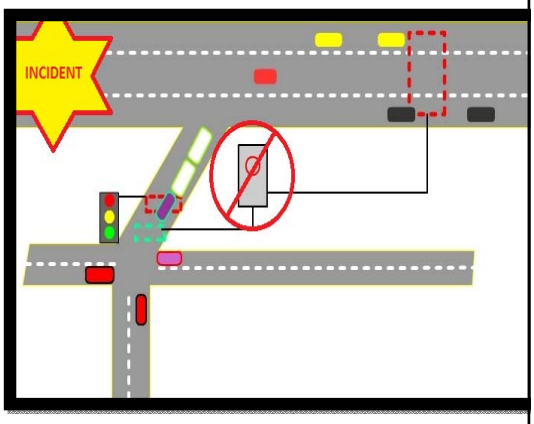


Control Strategies: Non-Recurrent Congestion

- **Inhibit Metering**

  maximize flow from arterial into freeway

  In case of incidents upstream of the on-ramp



Project Tasks

TASK	PROJECT MONTH											
	1	2	3	4	5	6	7	8	9	10	11	12
Task 1. HR Data Collection	■	■	■									
Task 2 Development of Strategies		■	■	■	■	■						
Task 3: Fwy/Arterial Control Strategies				■	■	■	■	■	■	■	■	
Task 4: Final Report											■	■

Task 1. HR Data Collection and Estimation of Performance Measures

- **Objective:**
  - Collect HR data from the three sites and calculate performance measures
- **Approach/Key Issues:**
  - Calculate performance measures
  - Sensitivity of estimates to detector caverage/accuracy
- **Deliverable:**
  - Database with HR data that is accessible and available to other researchers
  - Working paper – Calculation of performance measures

Task 2. Development and Testing Signal Control Strategies

- **Objective:**
  Collect and test control strategies based on HR data
- **Approach/Key Issues:**
  "Max Pressure" Strategy
  Test under various operating conditions
  Evaluation with .Q model
- **Deliverable:**
  Working paper – development and evaluation of signal control algorithms and simulation tools

Task 3. Development and Testing of Freeway/Arterial coordination Strategies

- **Objective:**
  Develop & test control strategies for selected operating scenarios
- **Approach/Key Issues:**
  Scenario selection
  Performance trade-offs: freeway vs. arterials
- **Deliverable:**
  Working paper – development and evaluation of freeway/arterial coordination strategies

Task 4. Preparation of Final Report

- **Objective:**
  - Documentation of research approach and findings
- **Approach/Key Issues:**
  - Assembly of working papers
  - Review comments
  - Suggestions for future research
- **Deliverable:**
  - Working paper – development and evaluation of freeway/arterial coordination strategies