Field Test of Combined VSL and CRM for Freeway Traffic Control

Project Kickoff Meeting

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Outline

- VSL and CRM for Freeway Traffic Control
- Progressive Program Plan for 4 Years
- Tasks for Phase 1
- Preliminary Consideration of Site Selection
VSL and CRM for Freeway Traffic Control

- Combined VSL & CRM - Backbone of ATM
- International and US Practices
- Combined VSL and CRM Strategy
- Bottleneck Flow Maximization
- Concept of Operation (ConOps)
- Implementation Related Issues
Combined VSL & CRM - Backbone of ATM

Pre-Trip planning & mode use selection

Traffic assignment for individual veh. routing

Demand Management

Capacity Management

Combined VSL & CRM for integrated mainstream and arterial traffic control

Bottleneck detection and management

Traffic Control Assistance Measures

Driver advice or mandate on: lane use limit; merge/lane-change assistance/limit; dynamic shoulder use; dynamic use of HOV/HOT lane; gap advice
International and US Practices

  - Increase in average throughput for congested periods of 3 to 7 percent;
  - Increase in overall capacity of 3 to 22 percent;
  - Decrease in primary incidents of 3 to 30 percent;
  - Decrease in secondary incidents of 40 to 50 percent;
  - Overall harmonization of speeds during congested periods;
  - Decreased headways and more uniform driver behavior;
  - Increase in trip reliability; and
  - Ability to delay onset of freeway breakdown
International and US Practices

- European Traffic Management Strategies (England, The Netherlands, New Zealand, Australia, …)
  - Speed Harmonization/Lane Control
  - Queue Warning
  - Dynamic Use of Hard Shoulder
  - Junction Control
  - Dynamic Re-routing
  - Traveler Information for pre-trip and in-route decisions
  - Coordinated Ramp Metering (HERO in Australia)
  - VSL (UK, the Netherlands, …)
International and US Practices

- US Traffic Management Strategies
  - Ramp Metering
  - Lane Management (or Managed Lane)
  - VSL and Managed Lanes (WSDOT)
  - Shoulder Use (TOD, Transit)
  - Pricing (HOT)
  - Traveler Information
Combined VSL and CRM Strategy

- **Control Objectives:**
  - Maximize bottleneck flow
  - Delay congestion start time if possible
  - Control density distribution
  - Achieve higher density (thus flow) for the same speed
  - Reduce total congestion time
  - Reduce shockwaves, including *Stop & Go*
  - Avoiding off-ramp blockage (always protecting its accessibility)
  - Minimize VHT and Maximize VMT system wide
  - Byproduct: Improve safety and emissions
Combined VSL and CRM Strategy

- Coordinated Ramp Metering (CRM)
  - Control density (or average density immediately downstream of the onramp) (mobility)
  - Balance demand and storage capacity at each onramp, taking into account queue length limit (mobility & equity)

- Benefits of CRM: Potential Local RM Problems
  - Conflict to mainline flow which could aggravate the congestion at bottlenecks in peak hours
  - Storage capacity of onramps may not be fully used due to the demand flow and the length differences between onramps
  - Significant negative impact to traffic in arterials
Combined VSL and CRM Strategy

- Variable Speed Limits (VSL)
  - Influence driver behavior ➔ reduce speed variance in the same lane and between lanes (safety and environment)
  - Avoid shock waves (mobility, safety and environment) ➔ to avoid first and secondary collision
  - Keep homogenous flow when density changes (mobility) ➔ same speed can be maintained for higher density
  - Smooth traffic when demands are too high, or RM has to be switched off due to ramp length limit (equity, mobility)

- VSL and CRM are complementary in function
  - RM only control the demand into the freeway; it has to be switch off if demand form local street is too high
  - VSL affects the mainline driver behavior (traffic flow)
  - Enforced VSL can regulate the flow as desired to maximize the bottleneck flow
Bottleneck Flow Maximization

Why is Bottleneck flow below capacity if its upstream is congested?

Answer: Feeding flow into the bottleneck is low – even if the speed in the bottleneck is increasing, the density is decreasing.
Bottleneck Flow Maximization

- Control strategy: to maximize bottleneck flow;
- Applicable bottleneck type: (virtual) lane drop and weaving
- How: (1) create a discharge section before the bottleneck; (2) regulate the discharge section flow to bottleneck capacity flow
- Example: flow of 3-lane discharge section could be made closer to (a 2-lane) bottleneck capacity flow
Implementation Related Issues

- VSL and CRM can be implemented independently
- When implementing CRM alone, the speed in the model just use the real time estimated traffic speed
- Critical to the success of field test → Data Health
- Traffic state parameter estimation
ConOps – VSL Only

PATH Control Computer

VSL Stand Alone for Freeway Corridor Traffic Control

TMC Computer

Caltrans PeMS 30s Real-time Data Server

FreeWave

Onsite Server Computer

FreeWave

Speed 35
For Max Flow
ConOps – CRM Only, Scheme 1

CRM Stand Alone for Freeway Corridor Traffic Control

Caltrans PeMS 30s Real-time Data Server

Wireless 3G modem

PATH Control Computer

TMC Computer

RT data

RM rate

CRM Rate

Cabinet 1
170/2670 Controller

Cabinet 2
170/2070 Controller

Cabinet 3
170/2070 Controller

Cabinet N
170/2070 Controller

Traffic detector
ConOps – Combined VSL & CRM

Combined VSL & CRM for Freeway Corridor Traffic Control

- Caltrans PeMS 30s Real-time Data Server
  - Wireless 3G modem
  - PATH Control Computer
    - Wireless 3G modem
  - PATH Control Computer 2
    - RM Rate
  - TMC Computer
    - Traffic detector

- Cabinet 1: 170/2670 Controller
- Cabinet 2: 170/2670 Controller
- Cabinet 3: 170/2670 Controller
- Cabinet N: 170/2670 Controller

- Onsite Server Computer
- FreeWave

- Speed 35 For Max Flow
ConOps – CRM Only, Scheme 2

CRM Stand Alone for Freeway Corridor Traffic Control

PATH Control Computer

TMC Computer

RT data

RM rate

RM Rate

Cabinet 1
170/2670 Controller

Cabinet 2
170/2970 Controller

Cabinet 3
170/2070 Controller

Cabinet N
170/2070 Controller

Traffic detector
ConOps – CRM Only, Scheme 3

CRM Stand Alone for Freeway Corridor Traffic Control

TMC Computer

Cabinet 1
170/2070 Controller

Cabinet 2
170/2070 Controller

Cabinet 3
170/2070 Controller

Cabinet N
170/2070 Controller

Traffic Detector
Implementation Related Issues

- Higher level control strategy
  - Demand below bottleneck capacity
  - Demand close to or over bottleneck capacity
  - VSL advisory using portable VMS

- Critical factors for implementation
  - Proper storage section
  - Onramp queue detection
  - Traffic state parameter estimation (data health)
  - Suitable advisory messages and VMS locations
Progressive Program Plan for 4 Years

- Phase 1: Preparations for Field Testing of Combined VSL & CRM
- Phase 2: Field Experiment of CRM
- Phase 3: Field Experiment of VSL
- Phase 4: Field Test Combining VSL & CRM
Phase 1: Preparations for Field Testing of Combined VSL & CRM (15 Months)

- Objectives:
  - To prepare for future field testing of Variable Speed Advisory (VSL) and Coordinated Ramp Metering (CRM).

- SOW:
  - Finalize site selection criteria and select proper site
  - Extensive literature review on VSL and CRM
  - Preparations for control computers and VMS at RFS
  - Define performance parameters for evaluation
  - Data collection and modeling of selected site
  - Validation of the VSL and CRM algorithms with simulation for the selected site
  - Preparations for use of 30 s real-time data from PeMS for supporting later stage tests
  - Preparing final report
Phase 2: Field Experiment of CRM (12 Months)

- Objectives:
  - Determine the technical feasibility, implement coordinated CRM and evaluate its effectiveness in improving corridor traffic flow.

- SOW:
  - Refine traffic state parameter estimation
  - Calibrate and refine traffic simulation for selected site
  - PATH computer to
    - interface with the TMC host computer
    - get real-time traffic data
    - send generated RM rate for selected freeway corridor
  - Evaluate effectiveness of CRM algorithm
  - Write Phase 3 report to document findings
Phase 3: Field Experiment of VSL (12 Months)

- **Objectives:**
  - Implement and test VSL at selected site for traffic flow and safety improvement

- **SOW:**
  - Retrieve real-time 30 s data from Caltrans PeMS
  - Use a PATH computer to control the display of VSL on portable VMS
  - Progressively switch on VSL displays for short time periods
  - Modify algorithms and tune the system based on observed effects on traffic flow and driver compliance
  - Collect data before and after VSL and analyze data for performance evaluation
  - Write Phase 2 report describing results
Phase 4: Field Test Combining VSL and CRM (12 Months)

- **Objectives:**
  - Test combined VSL & CRM and evaluate effectiveness

- **SOW:**
  - Improve algorithms based on previous tests
  - Implement combined VSL & CRM for selected site
  - Collect data before/after the control system activation
  - Systematic test of the combined algorithm
  - Analyze the data for evaluation of the performance
  - Assess merits and limitations of control algorithms, leading to implementation recommendations
  - Prepare Final Report to document all findings and recommendations
Tasks for Phase 1

Task 1. Setup advisory committee and extensive literature review
Task 2. Refine site selection criteria and select a proper test site
Task 3. Preparing VSL display and computers
Task 4. Define baseline performance of current RM control strategy
Task 5. Model Traffic Conditions at Selected Site
Task 6. Define extended performance measure parameters for evaluation
Task 7. Validate the developed VSL and CRM simulation and algorithms for the selected site
Task 8. Data analysis to prepare for later stage field test
Task 9. Prepare final report
Consideration of Site Selection

- Site Selection Criteria
- Some Candidate Sites
  - Highway 24 WB PM at Caldecott Tunnel
  - I-880 Nimitz Freeway
  - I-280 Near Saratoga Ave.
  - SR85-Camden, NB AM Peak
  - SR99-Mack Road (SB)
  - I-80 WB PM Peak
Site Selection Criteria

- Traffic demand is high to over-saturated in peak hours
- The corridor has a recurrent bottleneck downstream
- The most downstream (main) bottleneck has the minimum capacity or largest v/c ratio
- Congestion cause is lane reduction or virtual lane reduction
- Upstream of the main bottleneck has adequate storage section without off-ramp or has a separated off-lane
- Onramps are close enough
- All onramps are metered along the corridor for Phase 3 and 4; otherwise, the one without meter will cause problems
Site Selection Criteria

- Detection at critical locations: at the start of the bottleneck and 500 m upstream; each section has detectors 300~500 m apart; sensor health is important for good performance
- Onramp flow & queue detection is critical to CRM
- Off-ramp flow is ideal but not critical
- Hardware setup would allow CRM control (D4 TMC)
Highway 24 WB PM at Caldecott Tunnel
Highway 24 WB PM at Caldecott Tunnel
Highway 24 WB AM at Caldecott Tunnel

- Traffic volume in AM peak is rather high
- Only one VDS400989 about 1 mile upstream of the tunnel
- Loops at tunnel start need to be activated for traffic control
- Recurrent speed and flow drop between 7~9 am
- Two fixed VMS already available, with one at the expected Critical VMS Location
- No RM upstream
- Short term: when one tunnel is closed – lane reduction
- Long term: even if 4 tunnels are in operation, AM peak with two tunnels will still cause congestion, partly caused by high demand upstream and partly by lane reduction
- A possible candidate for VSL test only, but not for CRM
- Advantage: road geometry and infrastructure almost ready if D4 TMC can control the VMS in real-time
I-880 Nimitz Freeway
I-880 Nimitz Freeway
I-880 Nimitz Freeway - SB
I-880 Nimitz Freeway - SB

- SB traffic demand is high along the corridor
- Congestion for both AM & PM peak traffic: both flow and speed drop
- There is a lane reduction bottleneck
- A storage section upstream is available (about 1 mile)
- Onramp in the bottleneck needs metering (to be confirmed)
- Good RM infrastructure
- Sensor density and locations are OK; data system is good with healthy detectors
- With possible onramp and off ramp data detectors directly from D4
- Queue detection for onramps, unknown
- Possible candidate for combined VSL and CRM
- Needs further analysis
I-280 Near Saratoga Ave: SB PM Peak
I-280 Near Saratoga Ave, SB PM Peak
I-280 Near Saratoga Ave, SB PM Peak

- SB traffic demand is high along the corridor
- Congestion for PM peak traffic: both flow & speed drop
- A lane reduction bottleneck
- A storage section upstream is available
- Onramp in the bottleneck has metering
- Good RM infrastructure
- Sensor density, locations and data are OK
- Some onramp and off ramp data
- Has a strong interaction with arterial: Saratoga Ave
- Parallel arterials exist for re-routing
- Queue detection for onramps, unknown
- Possible candidate for combined VSL and CRM
- Collaborate with another Caltrans project: *Coordination of Freeway and Arterial Traffic Signal Control*
SR85 Camden, NB AM Peak
SR85 Camden, NB AM Peak
SR85 Camden, NB AM Peak

- NB AM peak traffic demand is high along the corridor
- Congestion for AM peak traffic: both flow & speed drop
- A lane reduction bottleneck
- A storage section upstream is available
- Onramp in the bottleneck has metering
- Good RM infrastructure
- Sensor density, locations and data are OK
- Has a strong interaction with arterial: Camden and SR17
- Parallel arterials exist for re-routing
- Queue detection for onramps, unknown
- Possible candidate for combined VSL and CRM
- Collaborate with another Caltrans project: Coordination of Freeway and Arterial Traffic Signal Control
SR99-Mack Road, SB PM Peak
SR99-Mack Road, SB PM Peak
SR99-Mack Road, SB PM Peak

- SB PM peak traffic demand is high along the corridor
- Congestion: both flow & speed drop
- A lane reduction bottleneck
- A storage section upstream (about 1 mile) is available
- Onramp in the bottleneck has metering
- Good RM infrastructure
- Sensor density, locations and some data are not available
- Parallel arterial exists for re-routing
- Queue detection for onramps (unknown)
- Possible candidate for combined VSL and CRM
I-80 WB PM Peak
I-80 WB PM Peak

I-80 West Bound to Toll Plaza
Example – I-80 W in PM Peak