DRISI

Caltrans Division of Research, Innovation and System Information

# Research Results

## Sustainable Operation of Arterial Networks

Simulation of actuated signals and the impact of vehicle-level control on intersection throughput

Transportation Safety and Mobility

JULY 2017

**Project Title:**
Sustainable Operation of Arterial Networks

**Task Number:** 3001

**Completion Date:** April 30, 2017

**Task Manager:**
Jose Perez,
Transportation Engineer
jose.perez @dot.ca.gov

### WHAT WAS THE NEED?

The 2015 Urban Mobility Scorecard estimates that the average U.S. commuter wastes 42 hours and 19 gallons of fuel per year because of congestion. This amounts to $960 annual congestion cost per commuter, which translates to $160B congestion cost nation-wide. Almost two thirds of congestion in large cities (and more than 80% in smaller urban areas) occur on city streets, and half of it happens during off-peak hours. The off-peak congestion affects not just private travelers, but shipping industry and manufacturers that depend on timely delivery of material. The off-peak congestion is also an evidence of poor arterial management.

The effectiveness of arterial congestion management depends on efficiency of signalized intersections. Intersection performance depends on the presence of actuation. When intersection bottlenecks cannot be resolved by tuning signal timing, adaptive cruise control (ACC) and cooperative adaptive cruise control (CACC) can be utilized to streamline vehicle flow for increasing the throughput of such intersections.

### WHAT WAS OUR GOAL?

The goal was to have researchers, through simulation, develop a suite of techniques that:
1. Enable assessment of intersection efficiency;
2. Model impact of ACC and CACC on arterial traffic flow; and
3. Make traffic on urban streets more reliable and predictable.

### WHAT DID WE DO?

Caltrans contracted the Regents of the University of California at Berkeley researchers to conduct the investigations under this task. Researchers focused on elements of link-level information – signal

Caltrans

DRISI provides solutions and knowledge that improves California's transportation system

ADA Notice: Users with accessibility issues may contact the California Department of Transportation, Division of Research, Innovation and System Information, MS-83 : (916) 654-8899, TTY 711, or Caltrans, DRISI – MS-83, P.O. Box 942873, Sacramento, CA 94273-0001

phase and timing (SPaT) estimation and prediction; and vehicle-level control – ACC and CACC. In SPaT analysis researchers presented several novel algorithms to estimate the residual duration of a signal phase for a semi-actuated intersection. These algorithms predict the times for all future phase transitions, based on previous phase measurements and on the real time information that locates the current time within the current phase. With respect to the vehicle-level control, researchers analyzed sensitivity of intersection throughput to car following models and related parameters. The Improved Intelligent Driver Model (IIDM) was chosen for traffic simulation. Finally, researchers implemented the platoon model in Simulation of Urban MObility (SUMO) and tested it in simulation of scenarios on Rollins Park network (the corresponding source code can be found at: https://github.com/ucbtrans/sumo-project).

## WHAT WAS THE OUTCOME?

Working toward the project goal, the outcome of this research were the following deliverables:

1. Arterial measurement data collection system;
2. Analysis of phasing and timing of actuated signals;
3. Evaluation of car following models and sensitivity of their parameters;
4. Model of ACC car following and CACC platooning in mixed traffic; and
5. Microsimulation model of signalized arterial network in Rollins Park, Maryland (MD), built from measurement data.

## WHAT IS THE BENEFIT?

Traffic management comprises feedback control of the road network infrastructure and demand management through traveler information, advisory messages and pricing. It happens on three levels: (1) at the vehicle level the car speed and headway are adjusted to increase throughput and safety; (2) at the road link level signal timings are optimized and special lanes re-allocated (e.g. bus lanes may be opened for everyone when necessary); and (3) at the network level traffic demand is managed via route advisory, day-to-day intersection timing adjustments, and traffic information dissemination.

The results of this project enable further investigation of the following research questions:

- How to combine vehicle flow measurements with SPaT estimation and how to use predicted vehicle flows for SPat prediction.
- Accurate SPaT prediction would enable speed advisory on links approaching the intersection to minimize stops and improve progression quality. This is important for mobility, energy efficiency and safety. However, such speed harmonization may reduce throughput of upstream intersections. The question is how to manage traffic speed at arterial links without creating bottlenecks at upstream intersections.
- The related question is about the impact of platooning in the speed harmonization effort. Specifically, how platoons should be managed when the corresponding green phase is not long enough to accommodate all vehicles in a platoon.
- How to incorporate network-level control that will balance the vehicle load on multiple routes connecting the same origin-destination pair after some of these routes were enhanced by the above mentioned link-level and vehicle-level control.

## LEARN MORE

View the Final Report

https://dot.ca.gov/-/media/dot-media/programs/research-innovation-system-information/documents/final-reports/ca17-3001-finalreport-a11y.pdf

The contents of this document reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the California Department of Transportation, the State of California, or the Federal Highway Administration. This document does not constitute a standard, specification, or regulation. No part of this publication should be construed as an endorsement for a commercial product, manufacturer, contractor, or consultant. Any trade names or photos of commercial products appearing in this document are for clarity only.

© Copyright 2020 California Department of Transportation
ALL RIGHTS RESERVED

## IMAGES

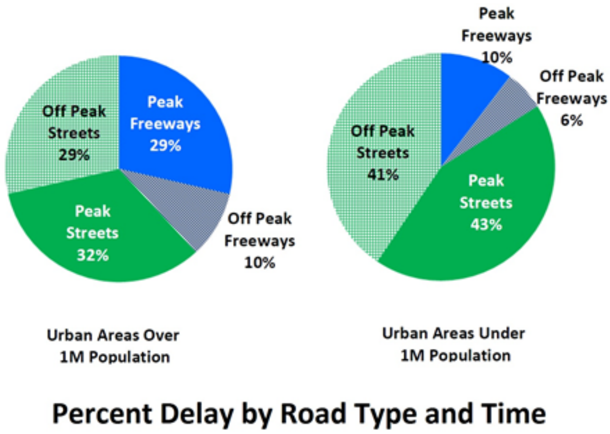



Image 1

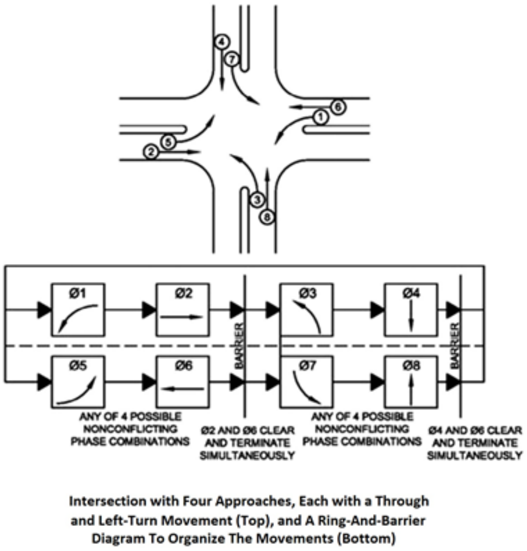



Image 2

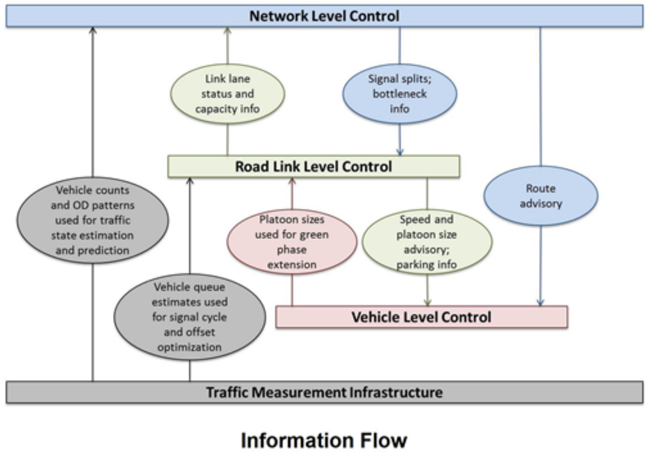



Image 3


Image 4

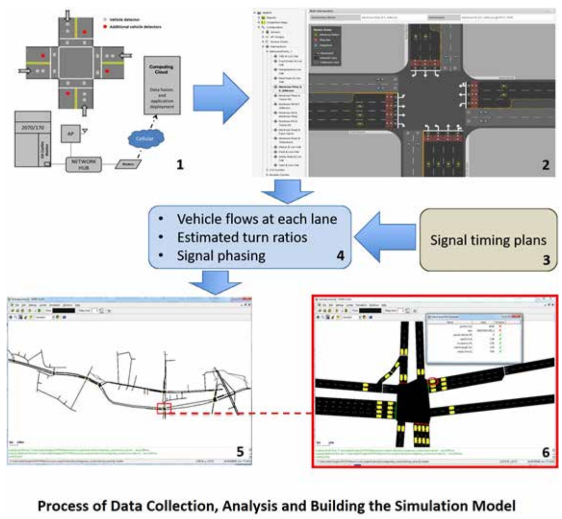
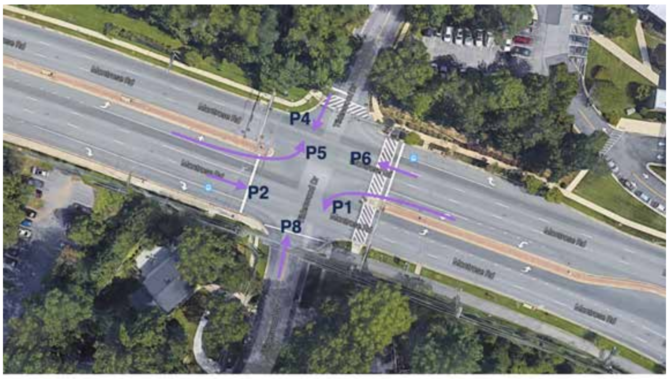



Image 5

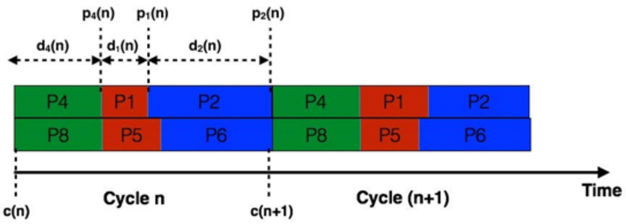
The contents of this document reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the California Department of Transportation, the State of California, or the Federal Highway Administration. This document does not constitute a standard, specification, or regulation. No part of this publication should be construed as an endorsement for a commercial product, manufacturer, contractor, or consultant. Any trade names or photos of commercial products appearing in this document are for clarity only.

© Copyright 2020 California Department of Transportation
ALL RIGHTS RESERVED



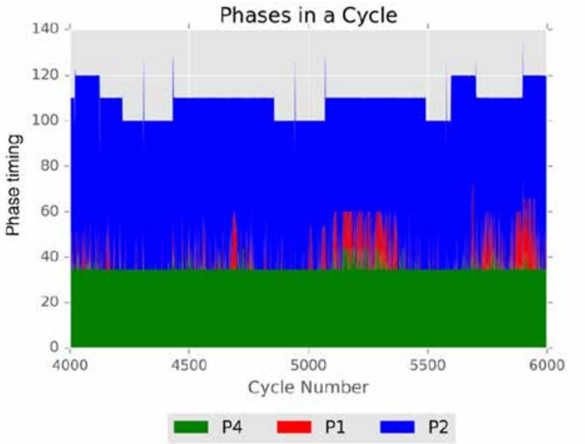

Intersection at Tildenwood Drive and Montrose Road

Image 6



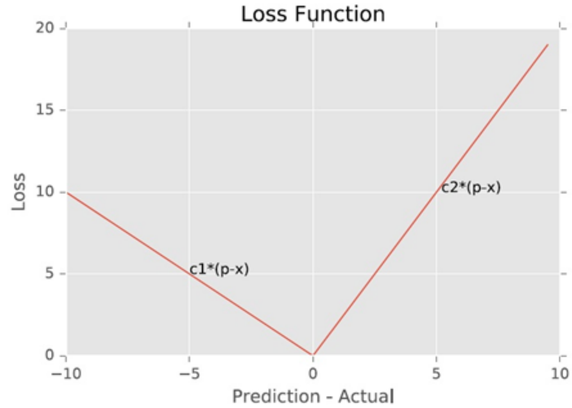

Variables Used to Define the Spat Estimation Problem

Image 7




Variation in Phase Durations Over 2,000 Cycles

Image 8

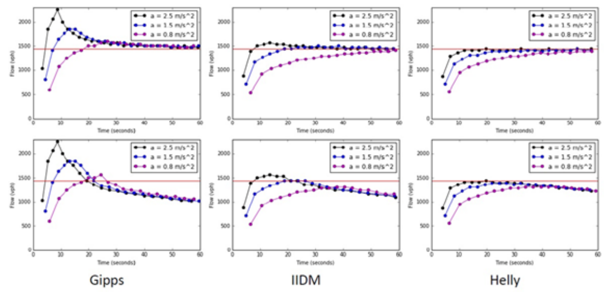



**Left:** Two Predictors

**Middle:** MAE Errors For Both Predictors: Conditional Expectation and Confidence-Based As A Function Of Observation Time *t*

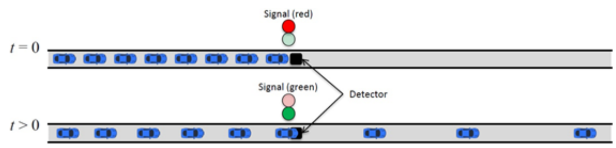
**Right:** MSE for Both Predictors

Image 9




Comparing Flows for Different Values of Maximal Acceleration ($a_{max}$) for Two Experiments - With the Free Road (Top), and With the Red Light Ahead (Bottom)

Image 10




Signal turns green at time t = 0, and vehicles start moving. The first vehicle has free road ahead.

Image 11

The contents of this document reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the California Department of Transportation, the State of California, or the Federal Highway Administration. This document does not constitute a standard, specification, or regulation. No part of this publication should be construed as an endorsement for a commercial product, manufacturer, contractor, or consultant. Any trade names or photos of commercial products appearing in this document are for clarity only.

© Copyright 2020 California Department of Transportation
ALL RIGHTS RESERVED