# 1st Symposium on "Management of Future Freeways and Urban Traffic Systems"

## Control of Freeway Corridors: Objectives, Performance Measures, Strategies

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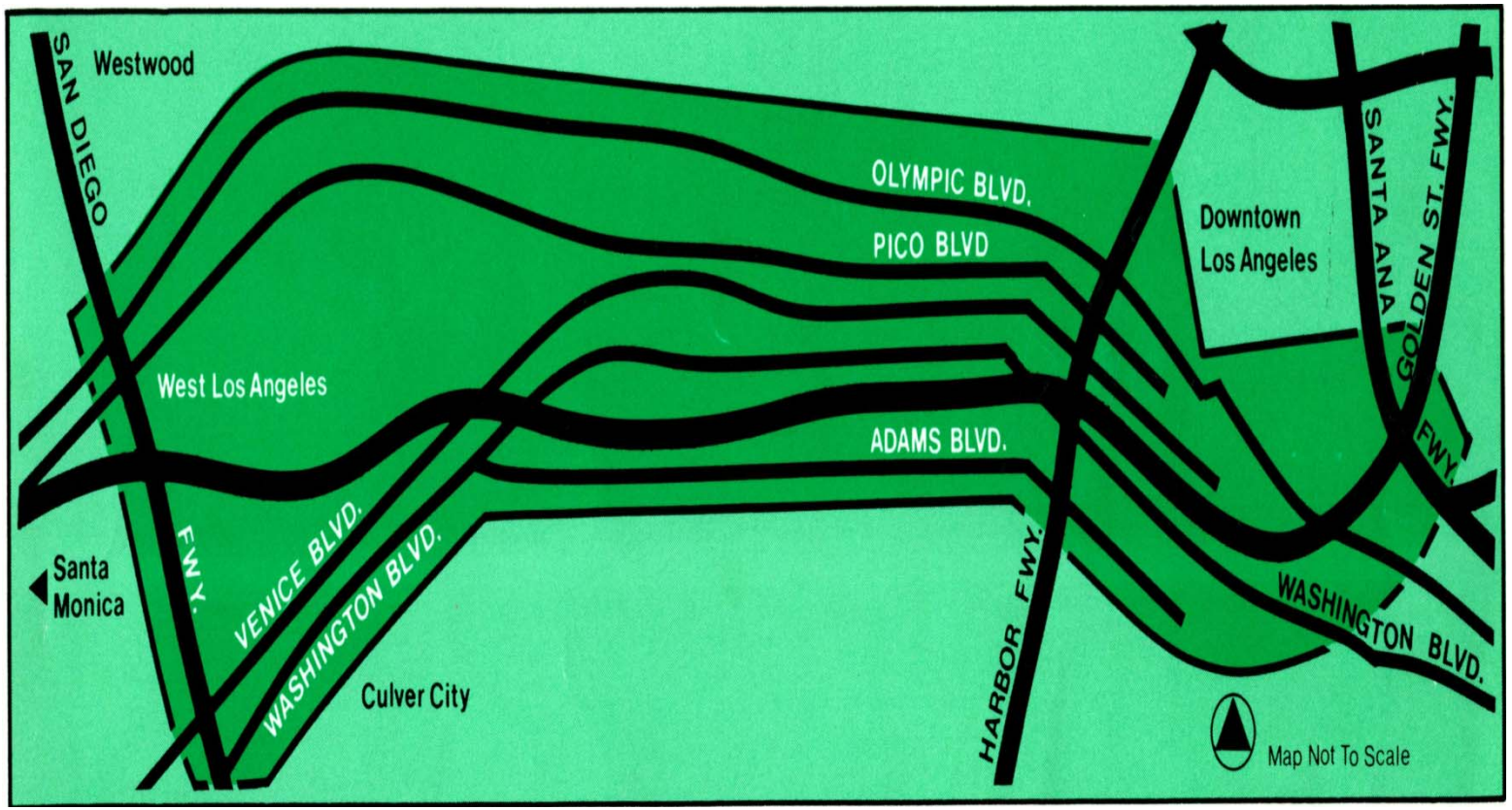
# Outline

- **Freeway Corridor management**
  - **Background/Problem Statement**
  - **National Programs: ICM**
- **Signalized Intersections: Performance Measurement**
- **Freeway-Arterial Coordination**
- **Looking Ahead**

# Background: Corridor Management

**Cooperative management of freeways and adjacent arterial networks**

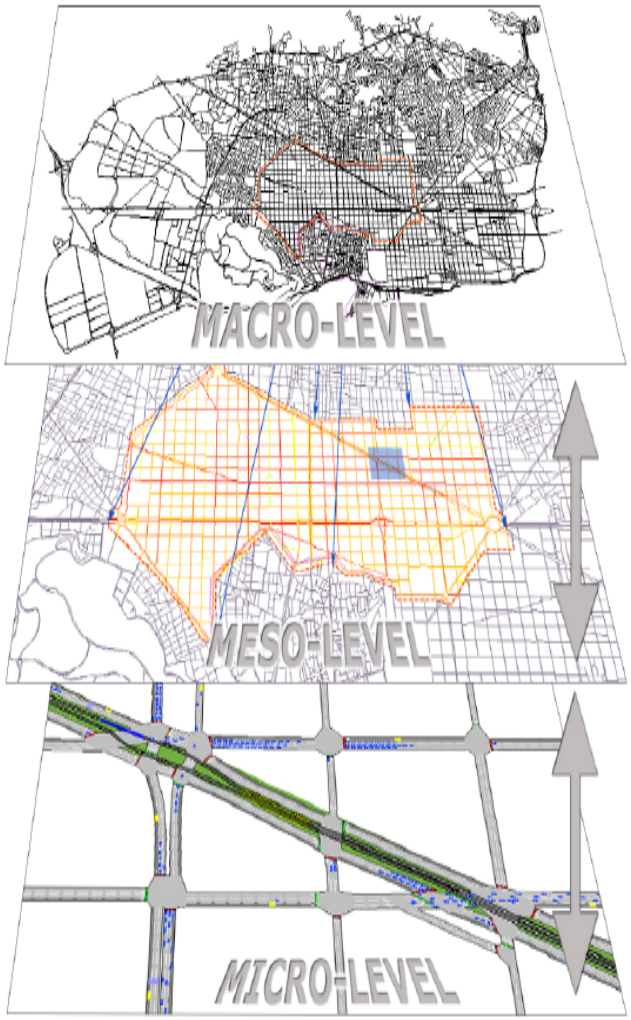
**Los Angeles, Smart Corridor 1988**



# Background: Corridor Management

## Corridor Traffic Management & Information Vision

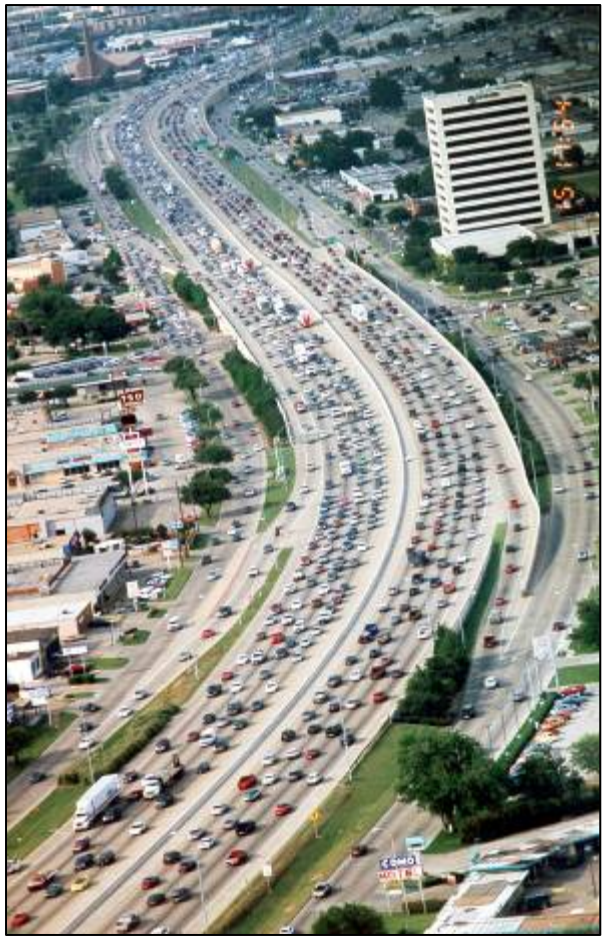
# USDOT ICM Program (1)

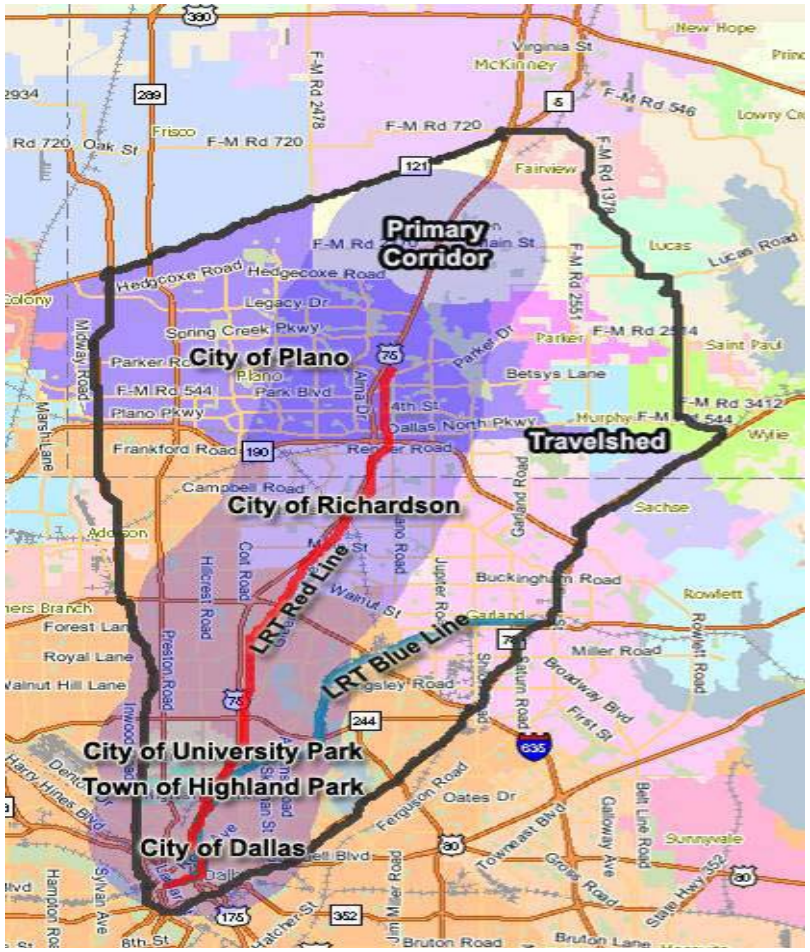



- Multimodal operations
- Complex modeling approaches
- Operational procedures/plans
- Institutional constraints
- Decision support systems
- Limited field evaluation
- Research Gaps
  - Data analytics
  - Control Algorithms

# USDOT ICM Program (2)

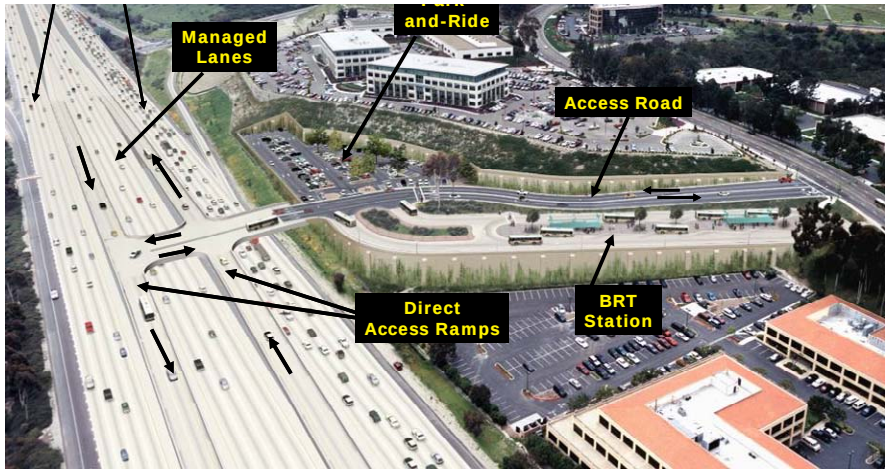
## US-75 ICM Corridor, Dallas, TX

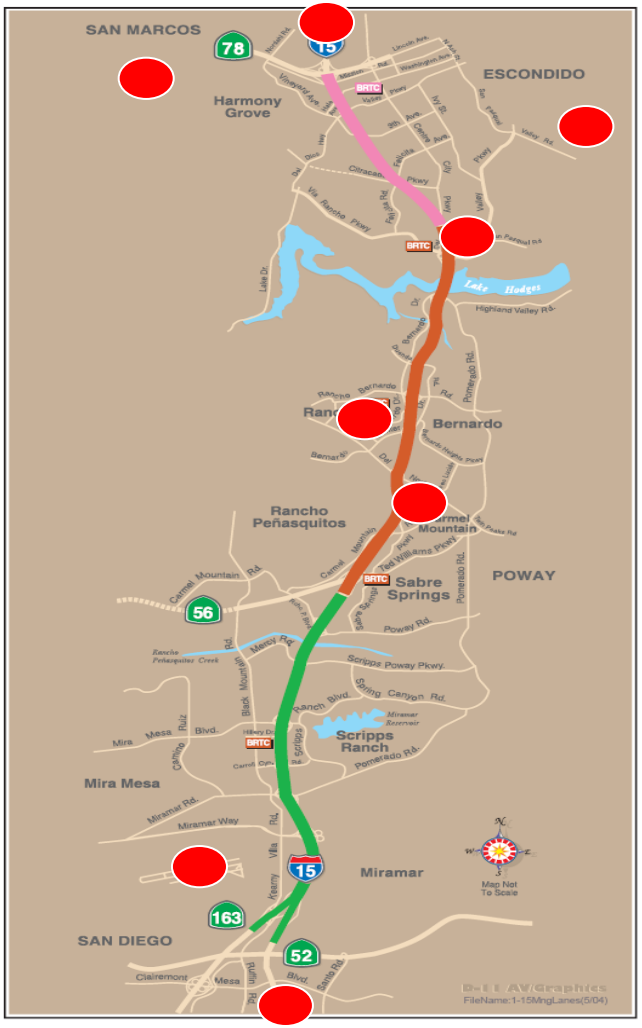




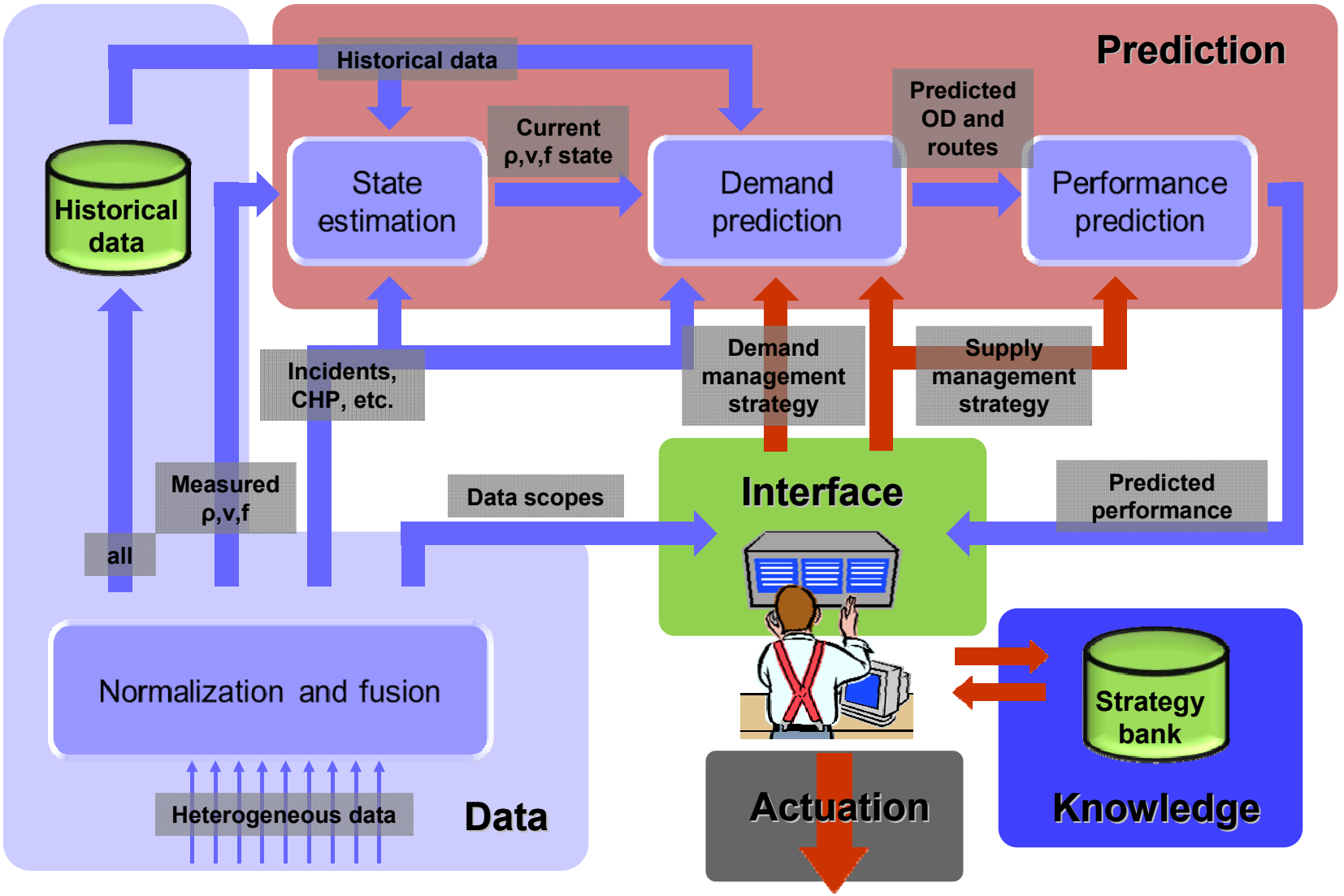
# USDOT ICM Program (3)

## I-15 ICM Corridor, San Diego, CA



# CA CC I-210: Decision Support



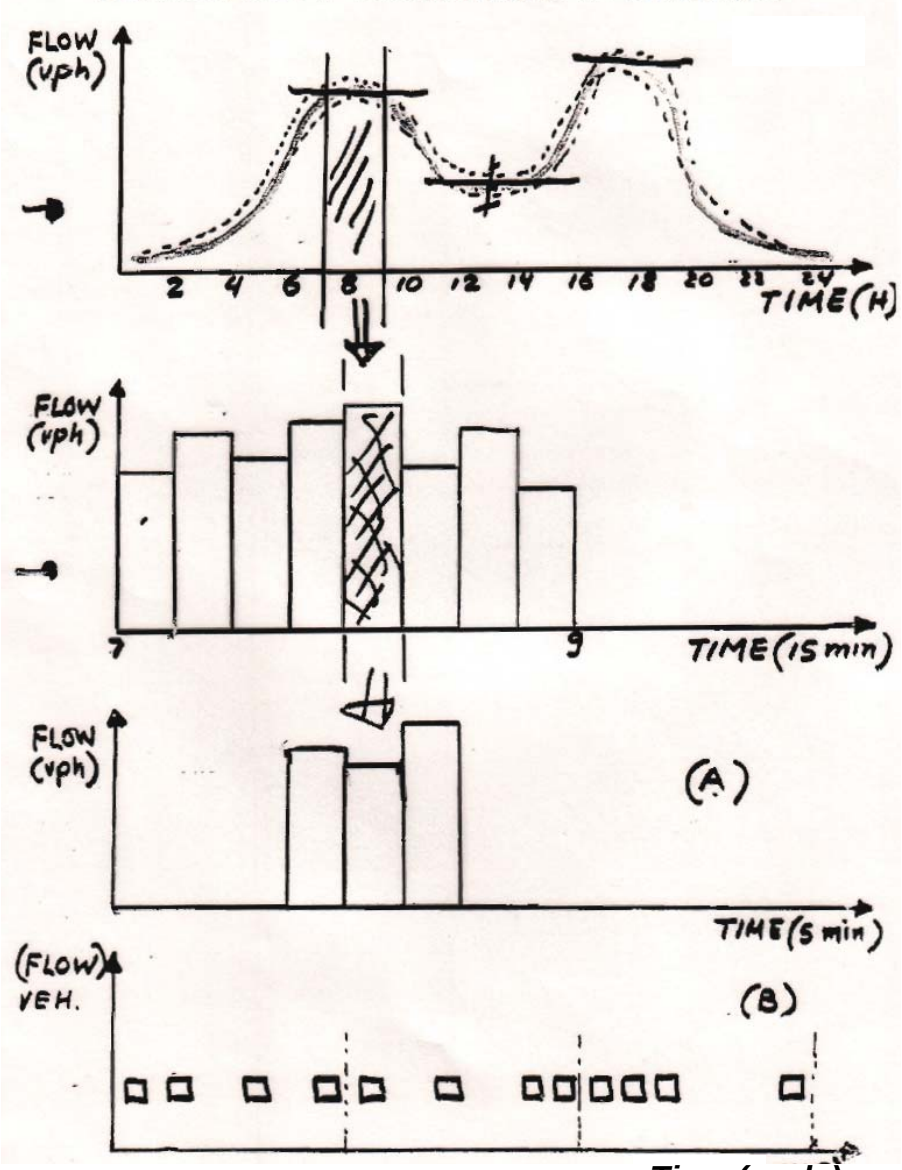
# Urban Arterials/Networks: Traffic Flow Variability vs. Control

**A**
- Fixed-Time Plans
- Time of Day (TOD)
- No Detection
- May be actuated

**B**
- Fixed time plans
- Traffic responsive plan selection
- System detection

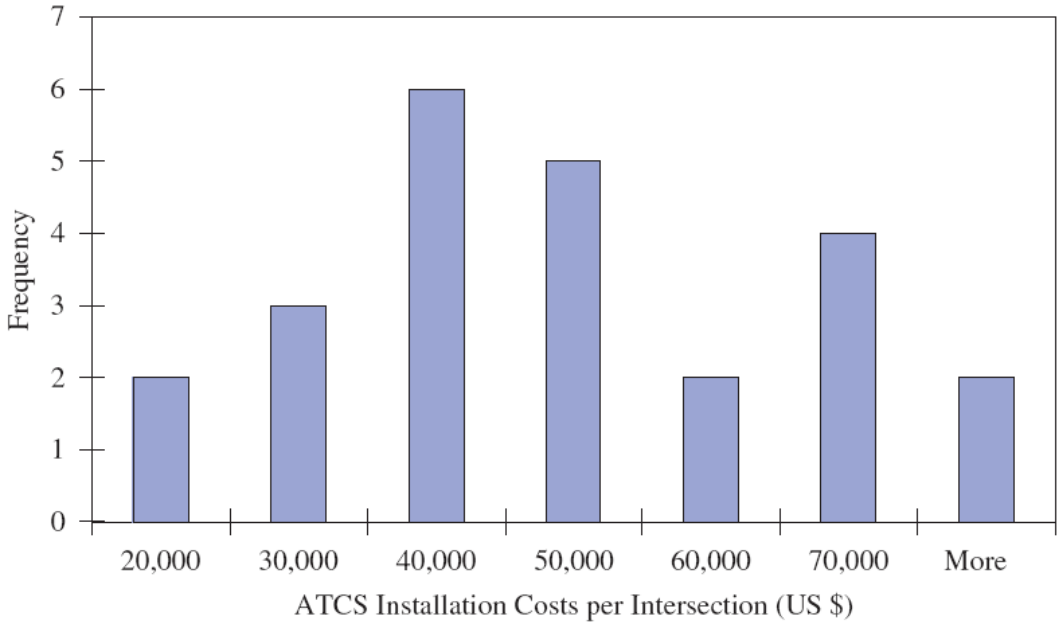
**C**
- Traffic responsive control
- On-line timing development
- Approach & system detection

**D**
- Adaptive control
- Measure & predict arrivals per cycle
- Extensive detection



# Arterial Networks: Traffic Control

- **Most signal systems fixed-time control**
  - **Limited data**
  - **Out-dated timing plans**
- **Adaptive systems**
  - **High cost**
  - **Complex to understand and operate**



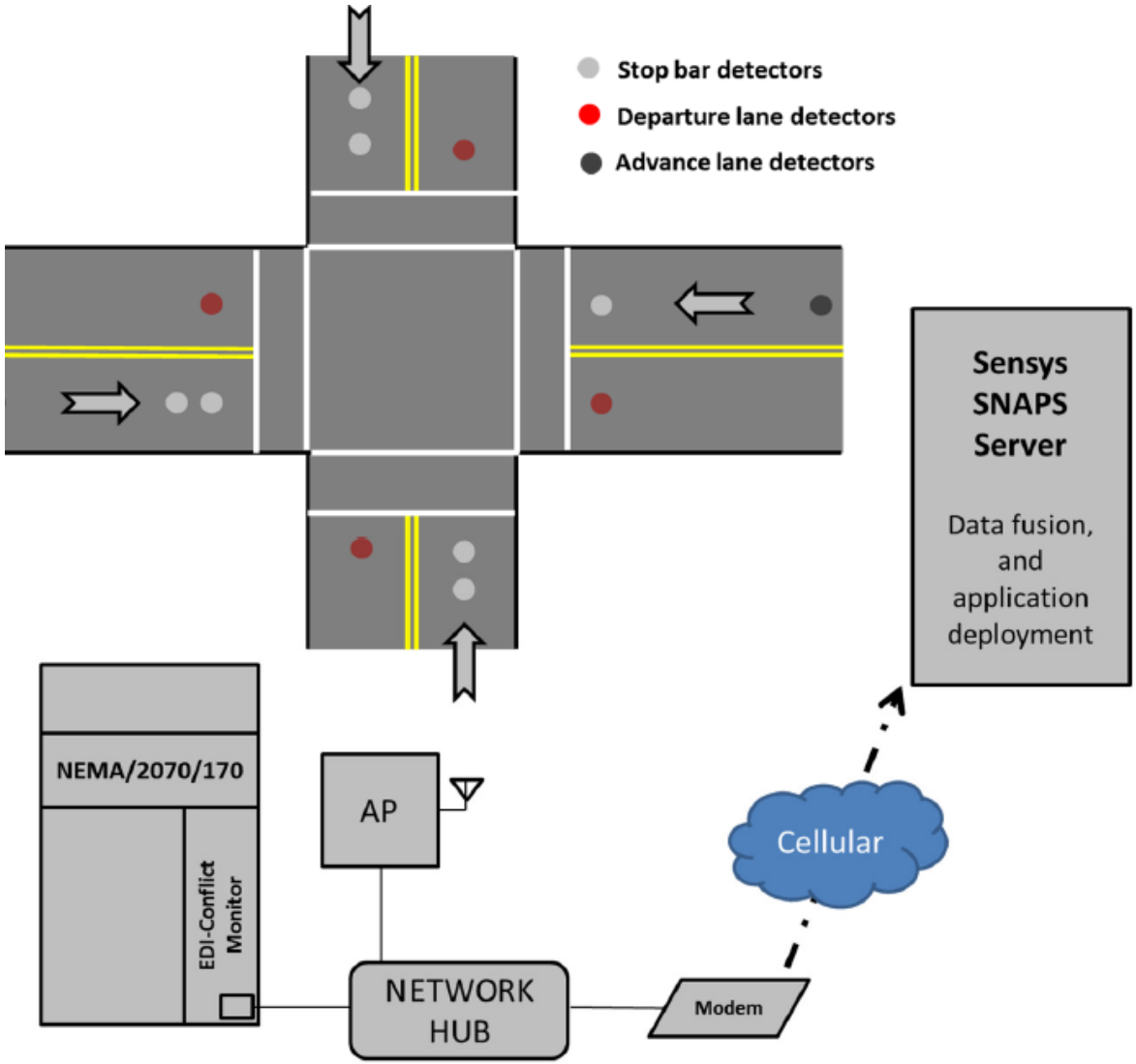

***Source: Alek Stevanovic, NCHRP Synthesis 403***

# Approach: Use of HR data*

- **Performance measures for operators and travelers**
  - Use of existing infrastructure
  - No interference with controller operation
- **Improving Signal Timing Plans**
  - Performance derived signal settings
  - Robust timing plans
- **On-Going/Future Work**
  - Traffic volume prediction
  - Safety (red light running)
  - Multimodal (pedestrians, bicycles)

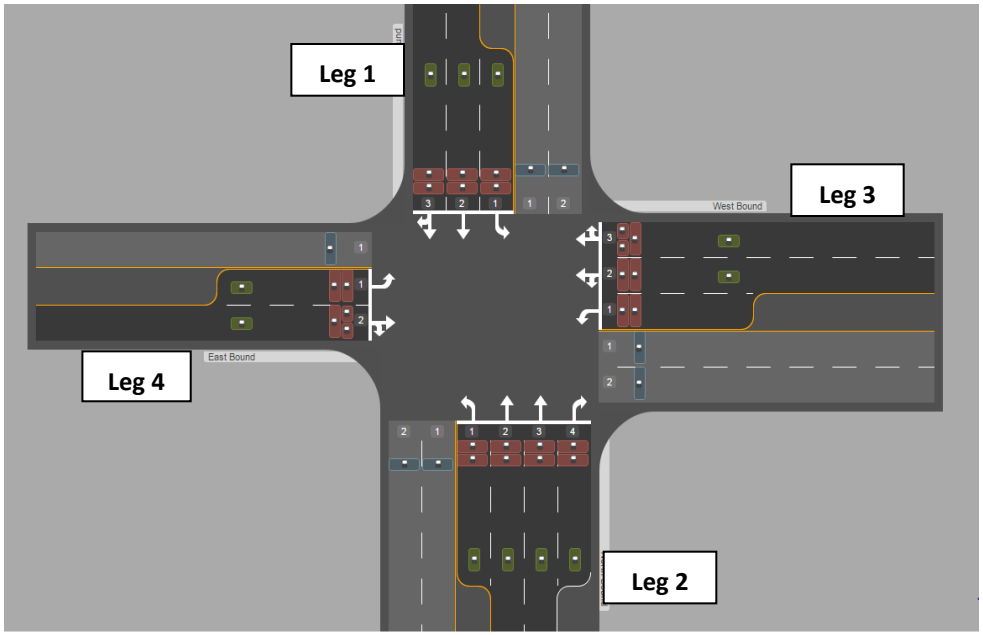
**Work with P. Varaiya & Sensys Networks*
*"Management of Urban Traffic with H-R Data" IEEE ITSC 2014*

# Data Collection System

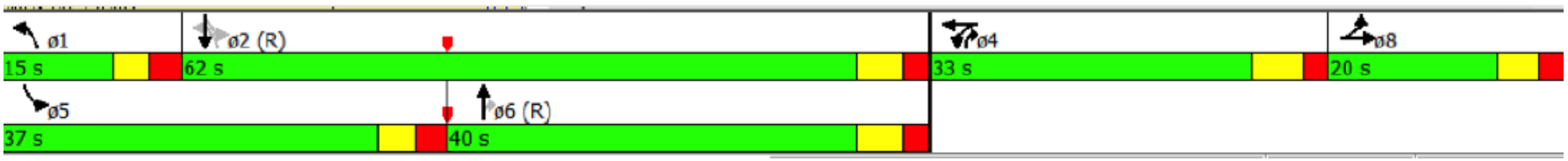



SENSYS networks

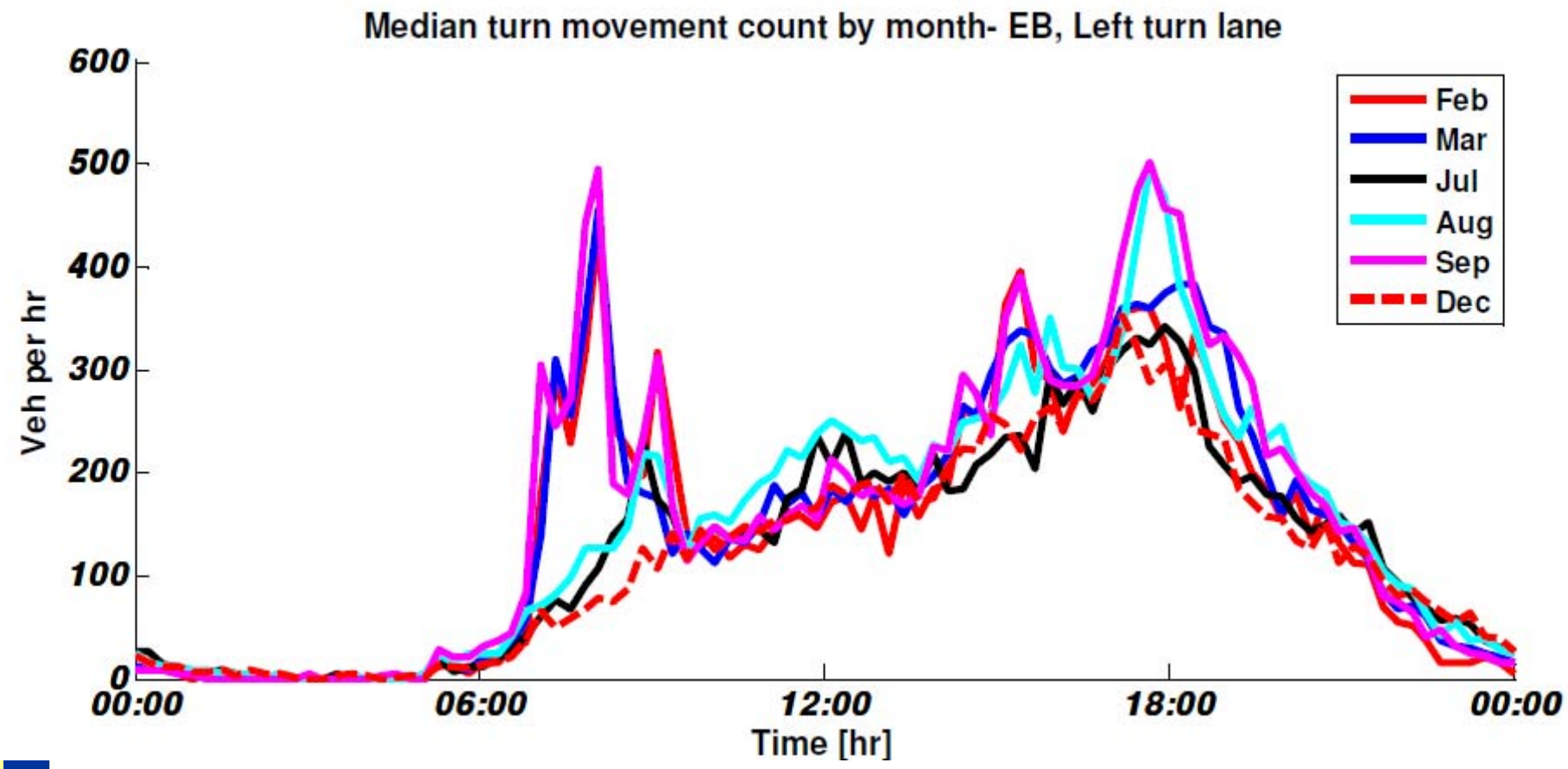
# Selected Test Site: Beaufort, SC



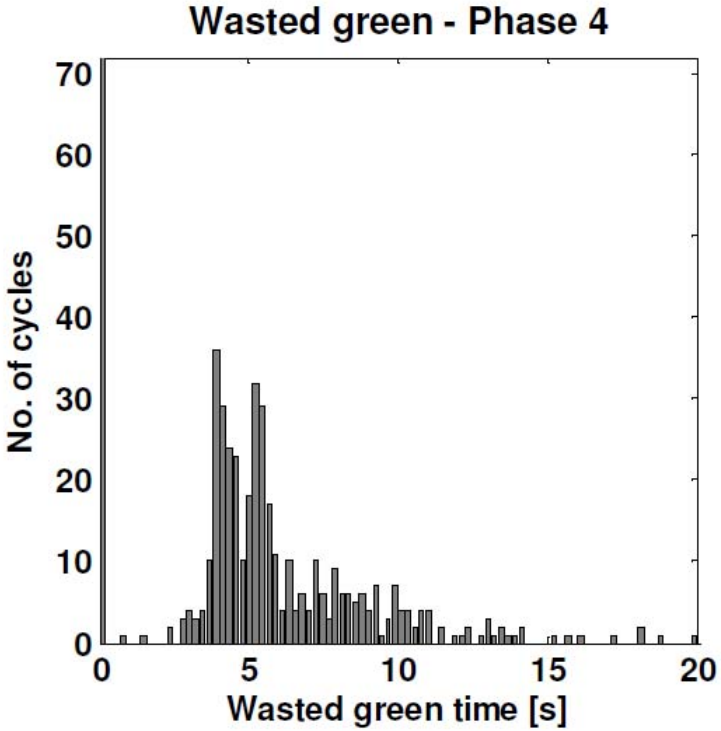


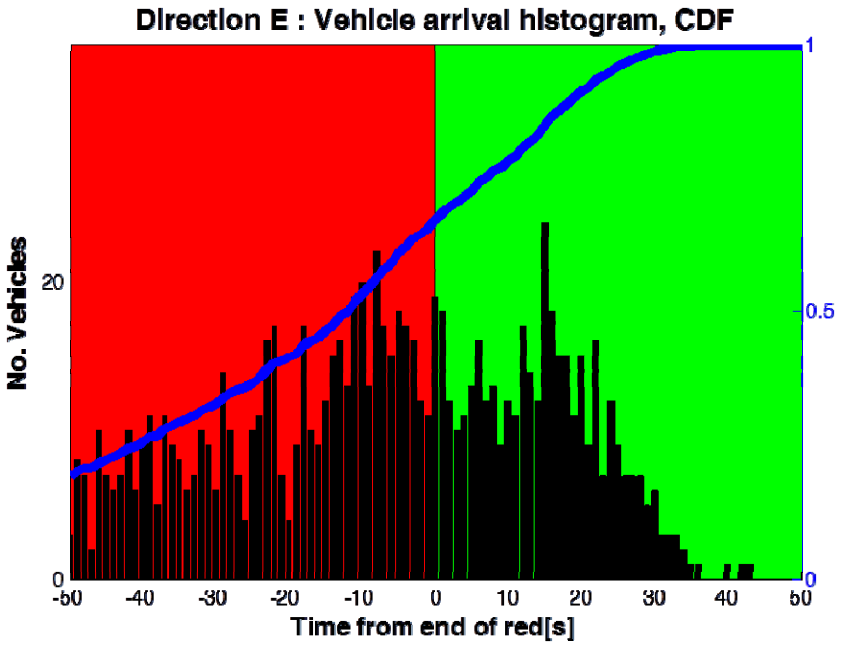


# Traffic Volume Patterns



# Signal Phase Operations

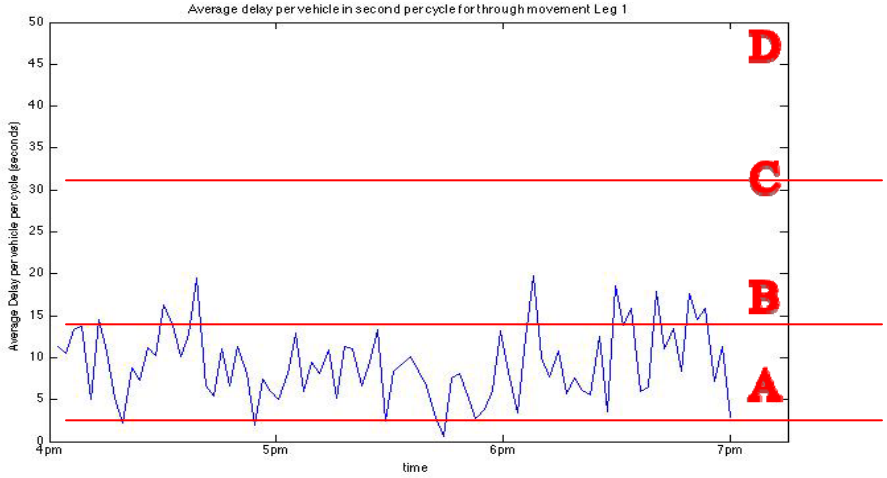


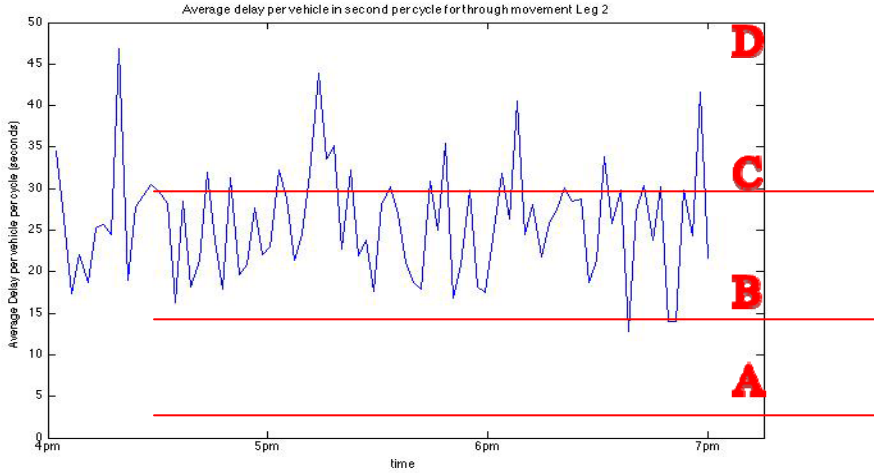

**Wasted green time:** time phase is active with no vehicle present and conflicting phase call

**Vehicle arrivals**: % arrivals on green

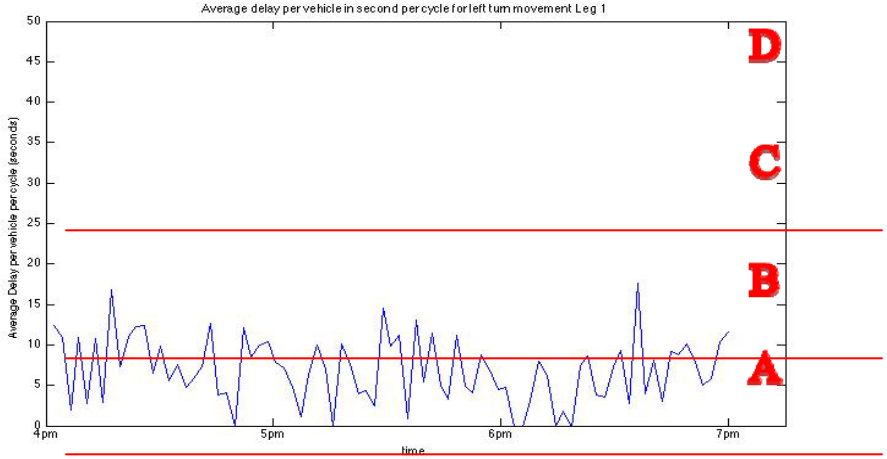
# Performance: Average Delay (sec/veh) HCM Level of Service (LOS)



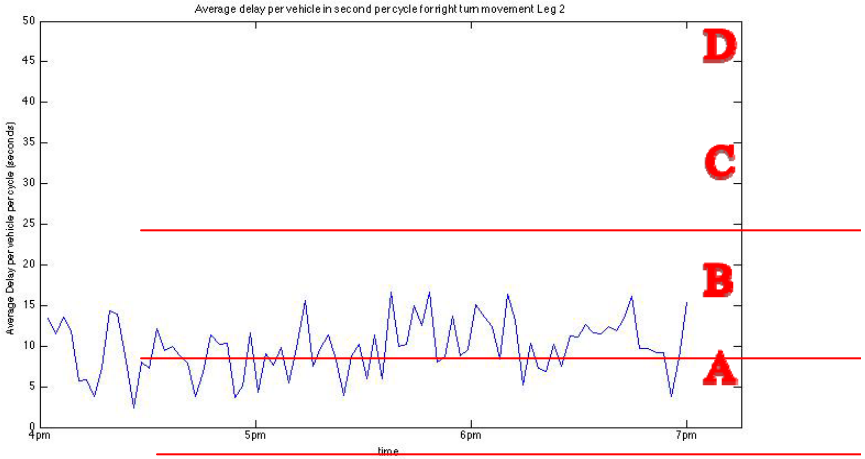

Through movement, Leg 1




Through movement, Leg 2

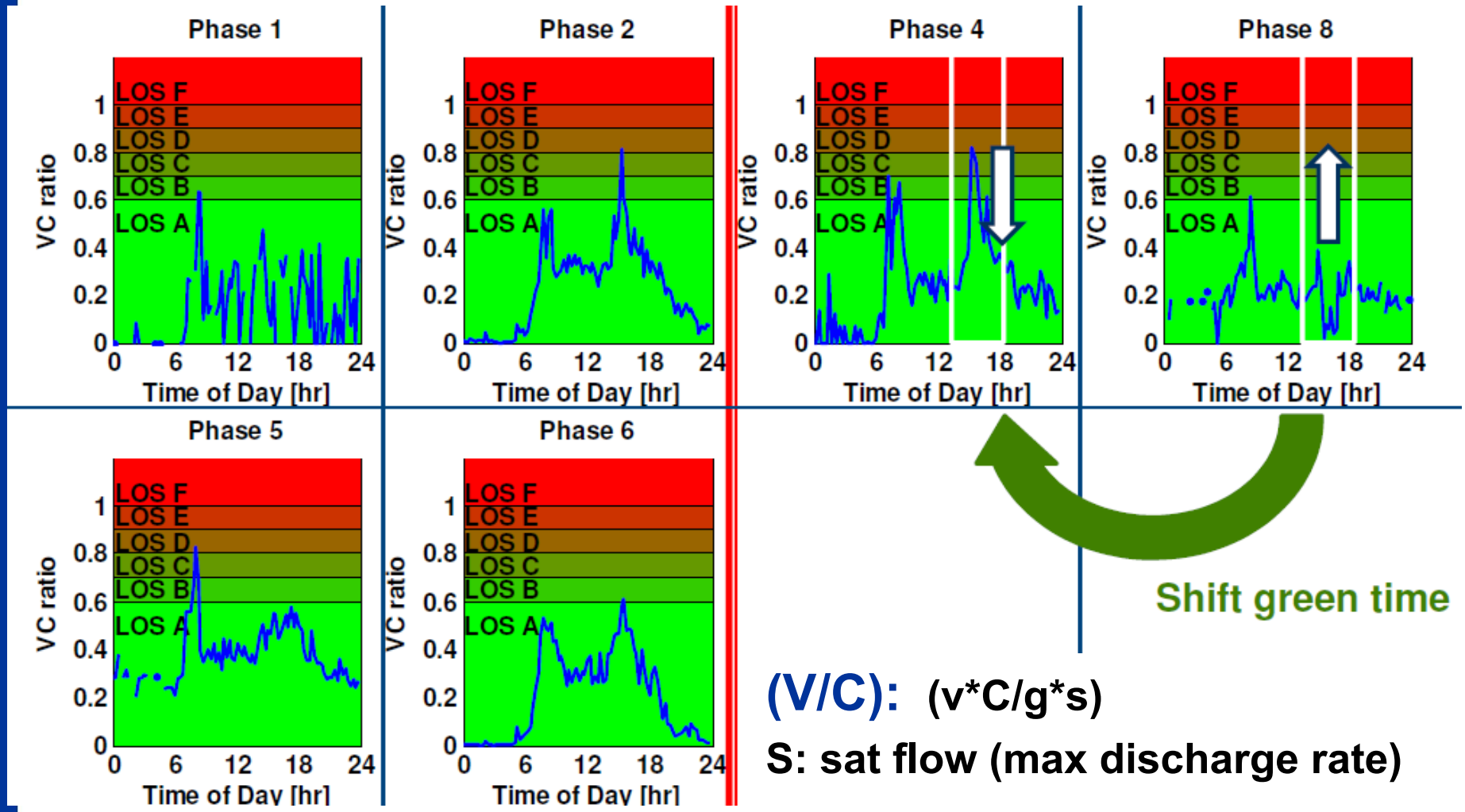



Left turn movement, Leg 1




Right turn movement, Leg 2

# Performance: V/c and LOS




**(V/C):** (v*C/g*s)

**S:** sat flow (max discharge rate)

**LOS:** Level of Service per HCM

# HR Data and Timing Plan Development

## Traditional Approach

Local adjustments based on spot observations (complaints)

↓

Field data collection of turning movement counts (one day)

↓

Apply signal optimization software to develop timing plan(s)

↓

Field implementation-fine tuning. Before and after studies (limited)

## Availability of HR Data

Assess existing intersection operations

- *Progression (% arrival on green)*
- *Capacity (V/c ratio)*
- *Delay*

↓

Develop and Implement Improved Settings

↓

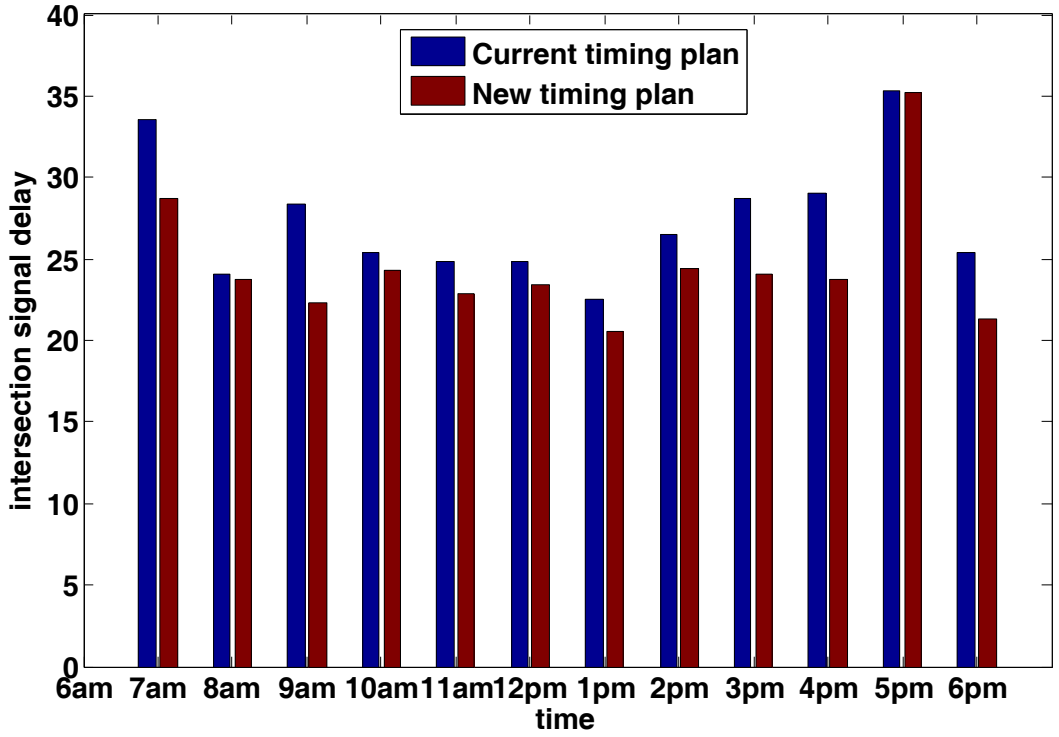
Evaluate performance

A*proach/intersection/system*

*Over time*

# Improving Signal Timing Plans

- Volume clustering – best set of volumes for the three timing plans available
- New timing plans reduce intersection signal delay by 10% on average*



# Summary: Use of HR data

- **Performance measures for operators and travelers**
  - Use of existing infrastructure
  - No interference with controller operation
- **Improving Signal Timing Plans**
  - Performance derived signal settings
  - Robust timing plans
- **On-Going/Future Work**
  - Traffic volume prediction
  - Safety (red light running)
  - Multimodal (pedestrians, bicycles)

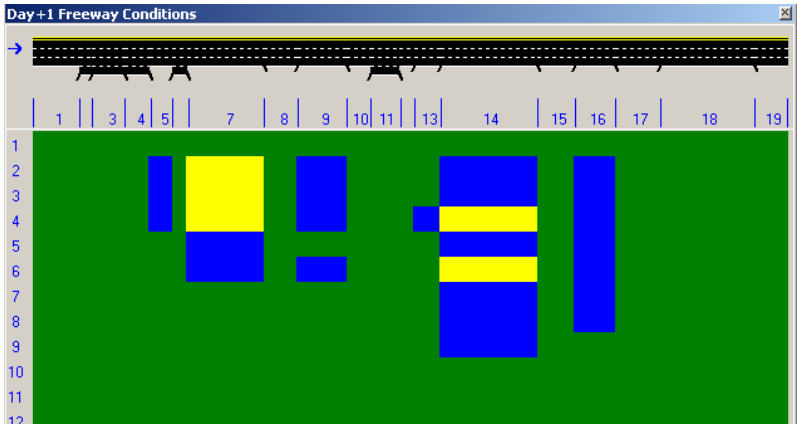
# II. Freeway – Arterial Coordination

- Important element of corridor management
- Existing coordination guidelines mostly address institutional issues (*example: FHWA Handbook*)
- Most approaches consist of scenarios with “flush” signal timing plans on arterials in case of freeway incidents
- Lack of Methodologies for Freeway-Arterial Interactions
- Spillbacks to- from ramps

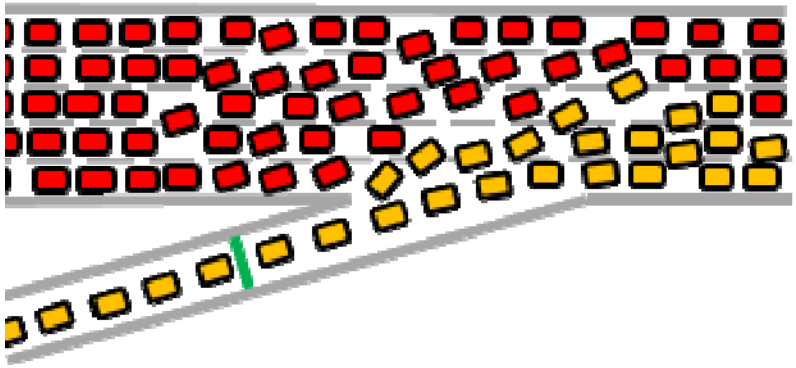
# Freeway Ramp Metering: Impacts

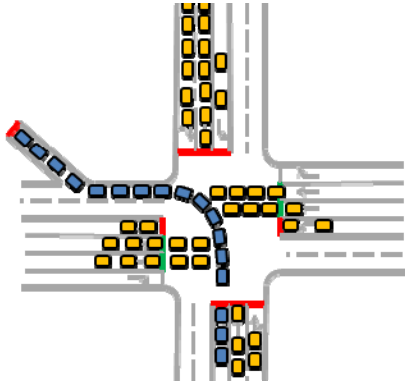
- Excessive delays to on-ramp vehicles
- Spillback to local streets
- Queue override –diminishes ramp metering benefits

## Freeway Mainline




## On Ramp Queues

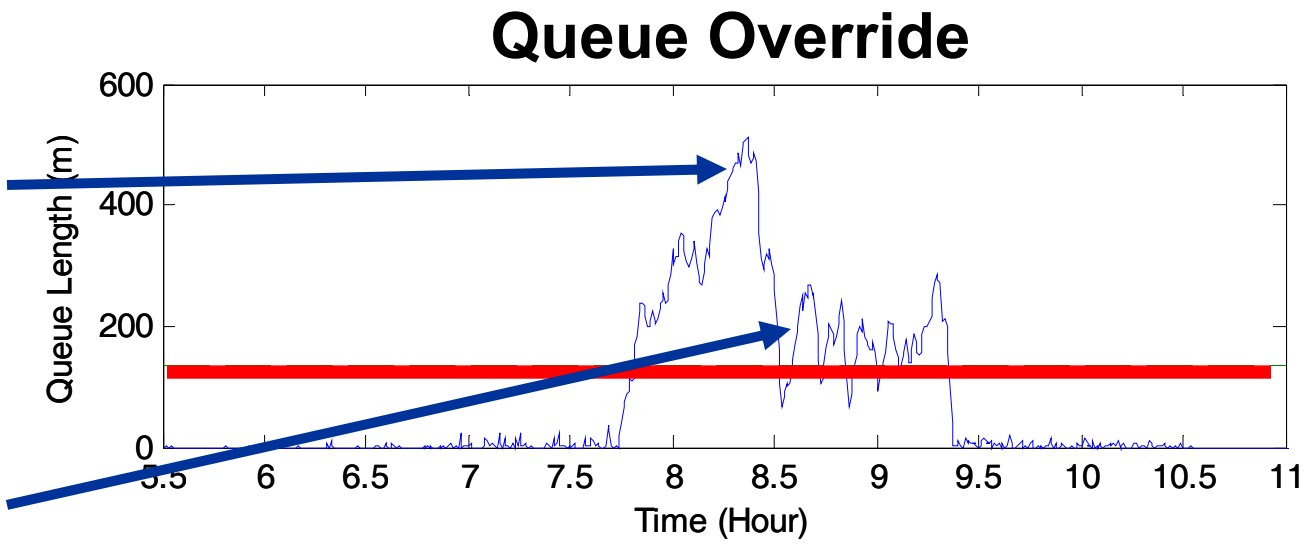



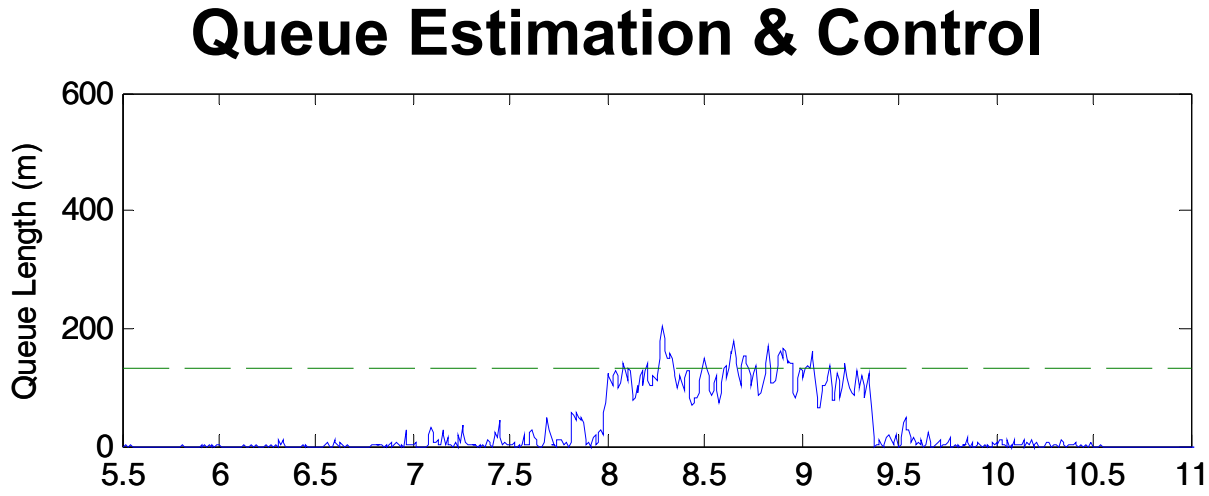


# On-Ramp Queue Control Regulator

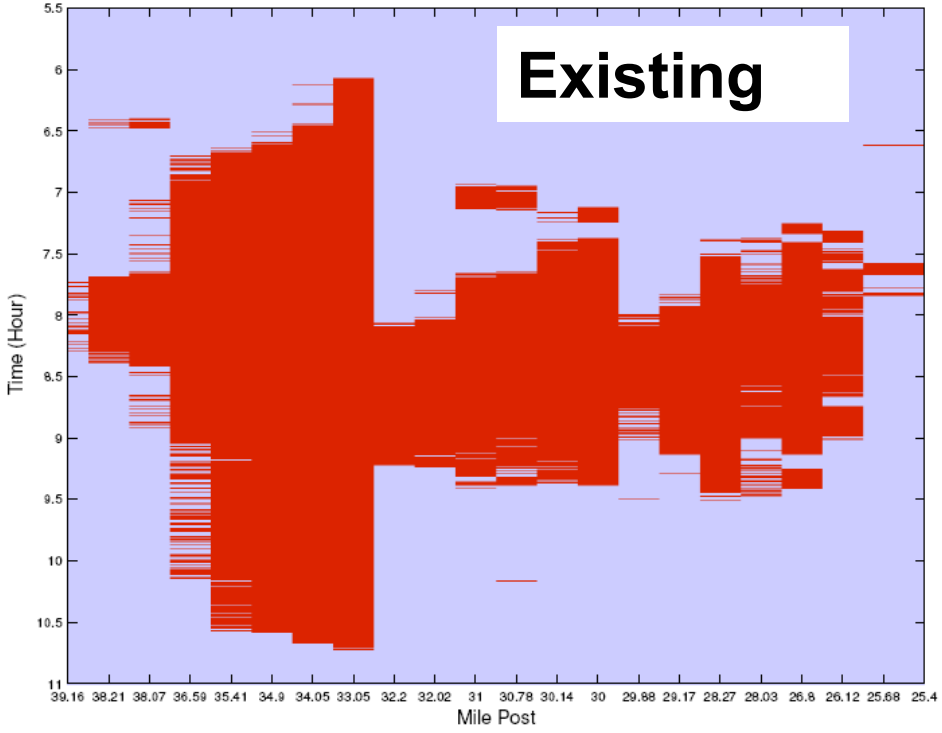
**Queue Override**

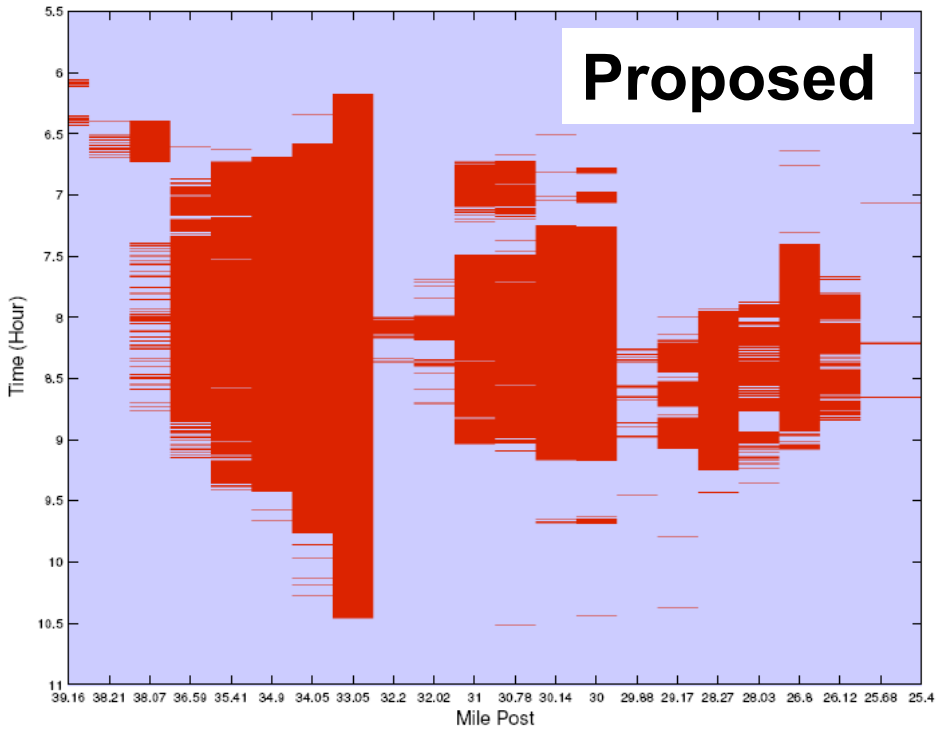
- **failed to limit the queue within the limits**
- **large variation in queue length**



# Application: Los Angeles I-210W



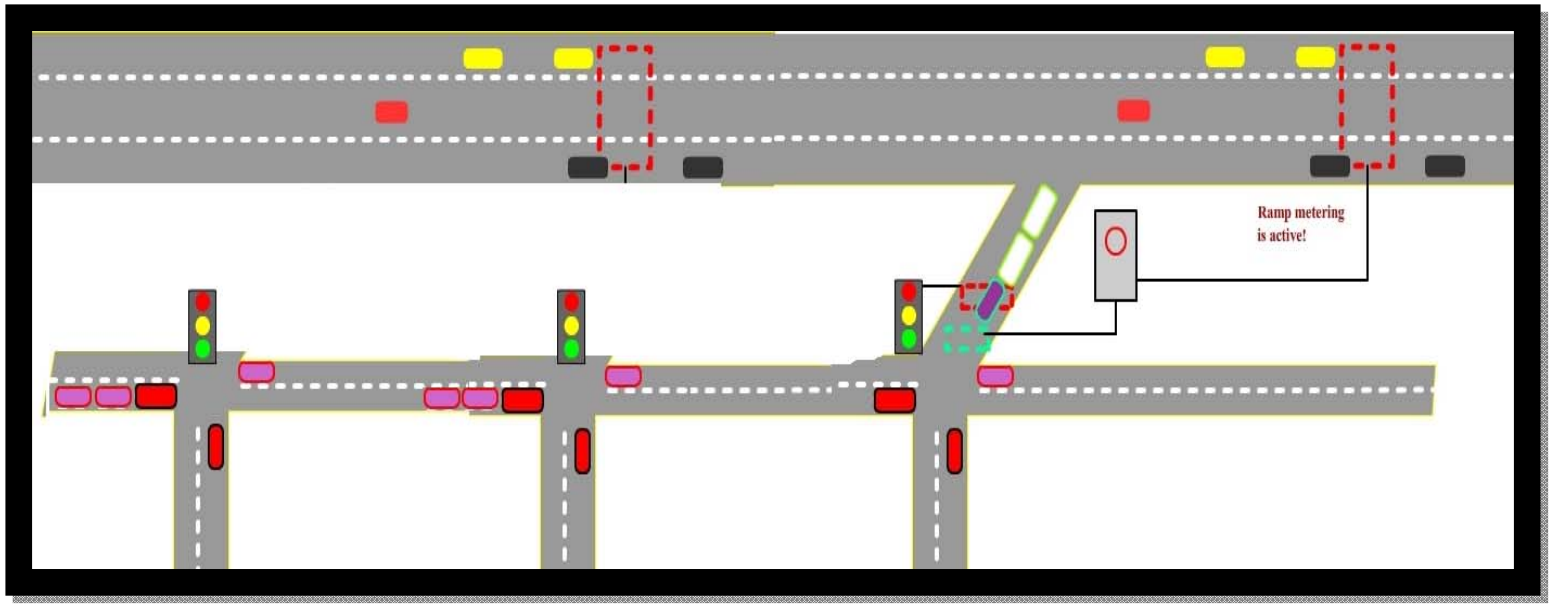

**Improvements:** **6% Travel Time/ 16% Delay Reduction**


***"Design, Field Implementation and Evaluation of Adaptive Ramp Metering Strategies," PATH Research Report UCB-2005-2***

**"Analysis of Queue Estimation Methods Using Wireless Magnetic Sensors, " TRR 2229, 2011**

# Proposed on-Ramp Access Control (1)

**Determine the signal settings to avoid queue spillover from ramp metering and result in queue override**




## Constraints

**Serve the traffic demand on arterial phases**

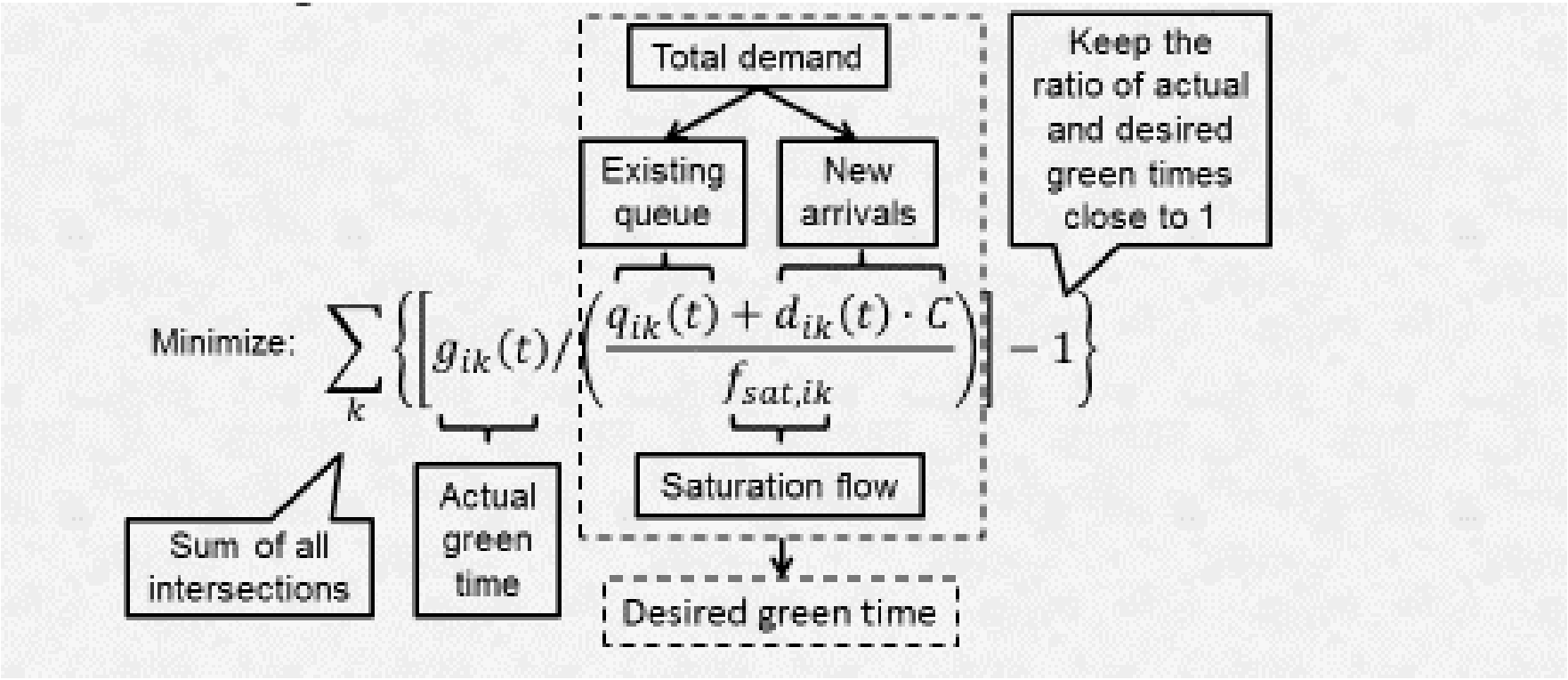
**Arterial link storage (arterial spillback)**

**Minimum phase green times**

# Proposed on-Ramp Access Control (2)

## Minimize the ratio of actual and desired green times per signal phase

**Desired green time: minimum green time to serve the traffic demand**



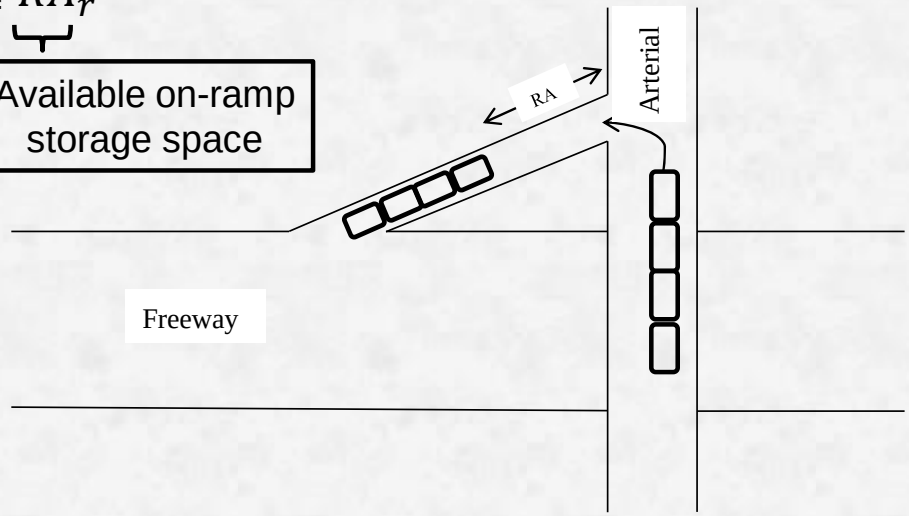
# Proposed on-Ramp Access Control (3)

## 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:

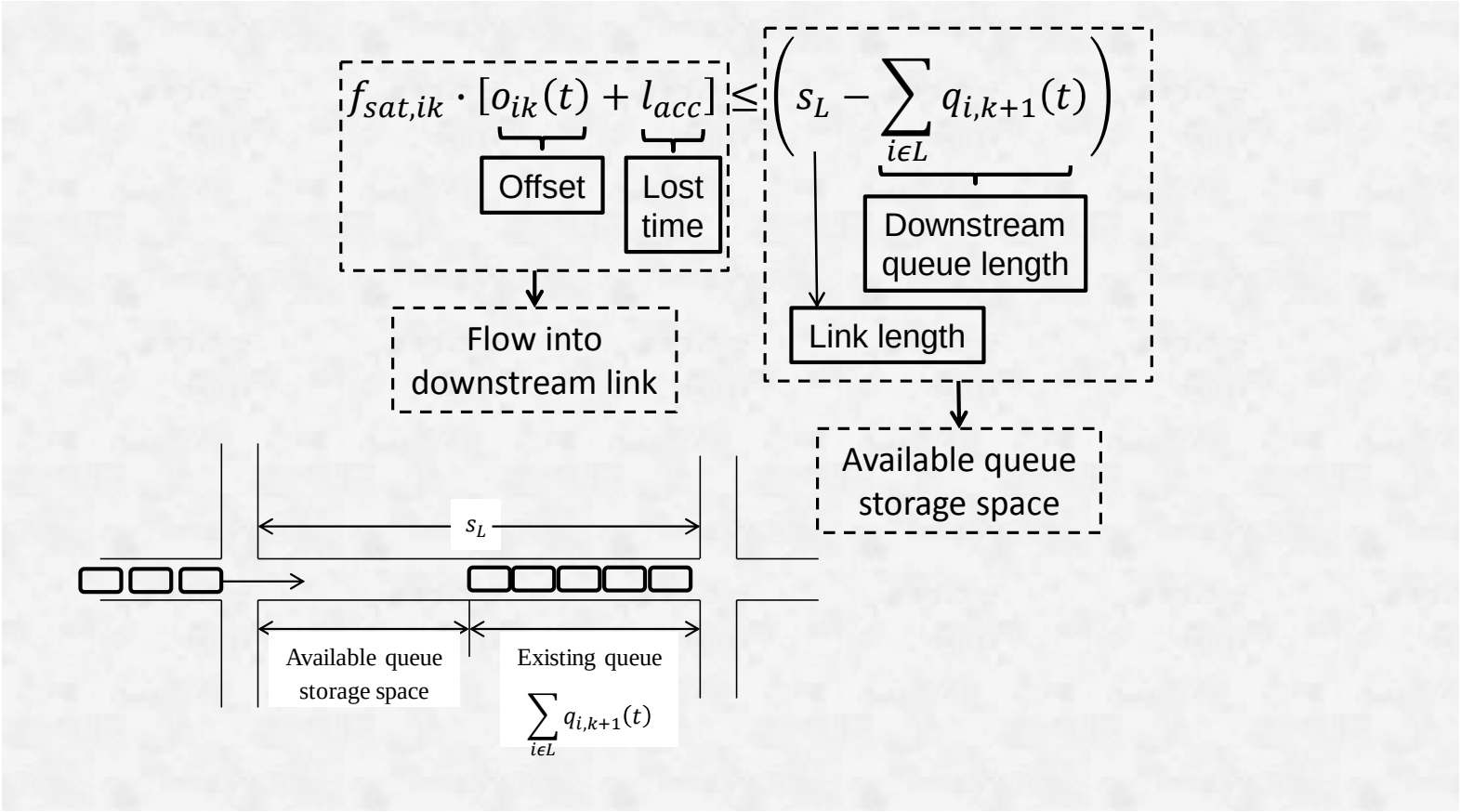
$$\underbrace{\sum_{i \in R} f_{sat,ik} \cdot g_{ik}(t)}_{\text{Phases for on-ramp access}} \leq \underbrace{RA_r}_{\text{Available on-ramp storage space}}$$

Total flow onto freeway on-ramp



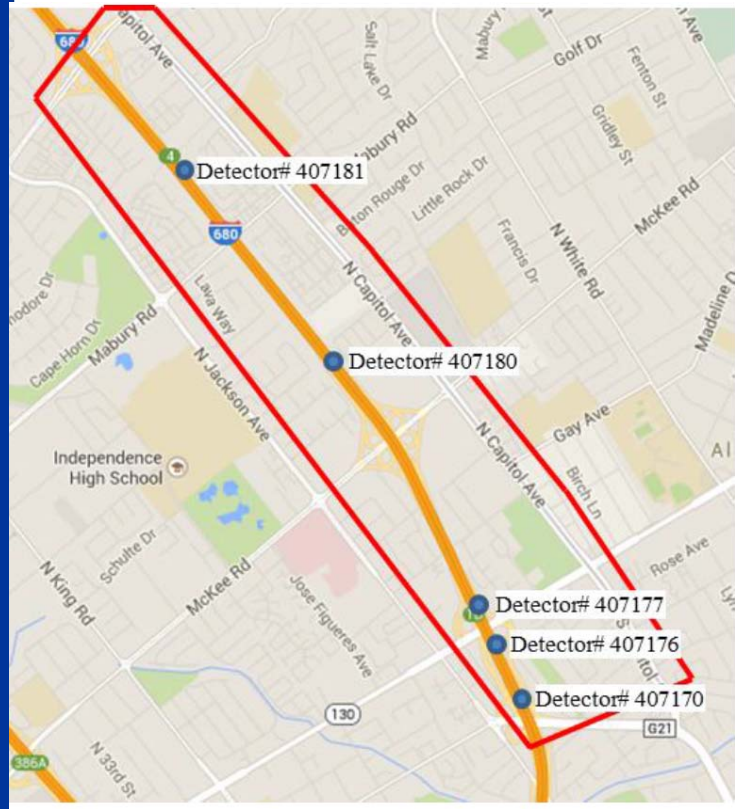
# Proposed on-Ramp Access Control (4)

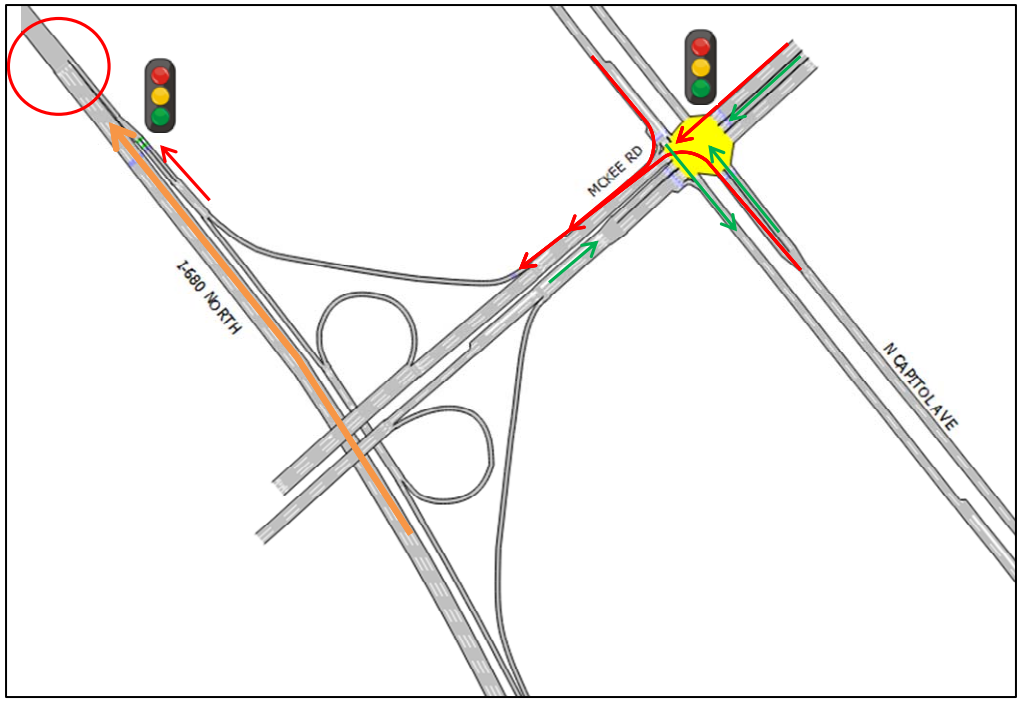
## Constraint: Arterial link storage



# Application: Test Site

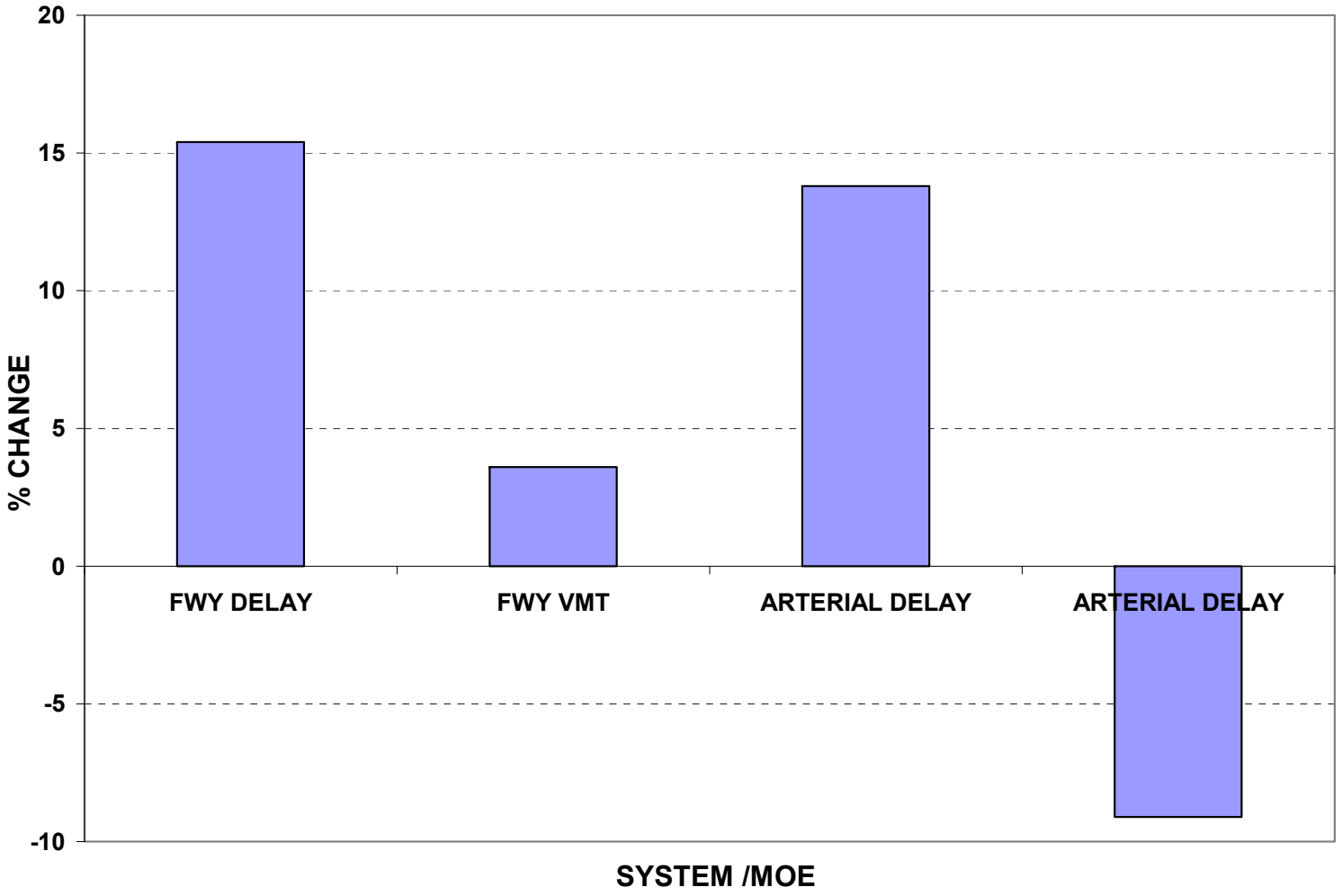
## Test Site: I-680, San Jose CA




- **AIMSUN Microscopic Simulator**

# Application: Findings



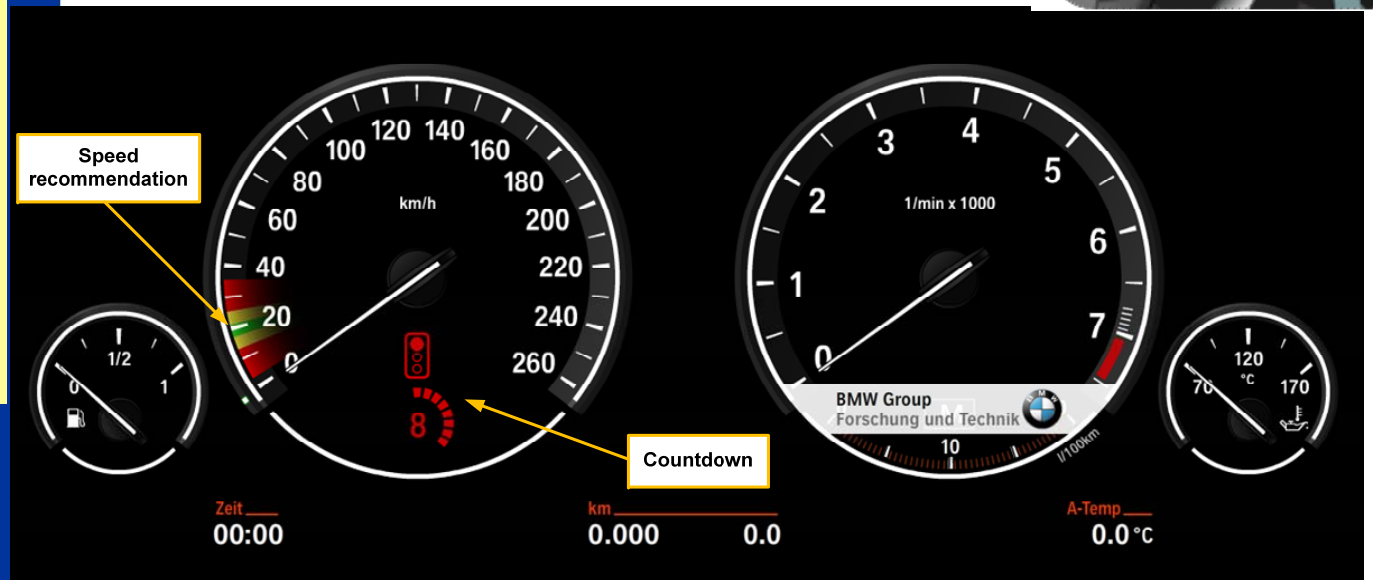
# Looking Ahead: Connected Vehicles

"Here I am"

V2V and V2I

V2I Example: SPaT message

Application: Dynamic Speed Advisory (source: UC & BMW)

# Field Test Results*

**Uninformed Driver (Baseline Scenario): no speed recommendation**

**Informed Driver: follow speed recommendation**

**Individual Vehicle Priority & Uninformed Driver: no speed recommendation. Intersection adapts timing with individual vehicle priority**

**Individual Vehicle Priority & Informed Driver: follow speed recommendation. Intersection adapts timing with individual vehicle priority**

| | Uninformed Driver | Informed Driver | Uninformed Driver &APIV | Informed Driver &APIV |
|---|---|---|---|---|
| Fuel (L/100KM) | 10.23 | 8.84 | 8.28 | 7.33 |
| Improvement | Base Scenario | -13.60% | -19.10% | -28.40% |

**https://www.fhwa.dot.gov/multimedia/research/advancedresearch/index.cfm*

*" Advanced Signal Control Strategies," PATH Research Report UCB-2013-3*

# Looking Ahead: Beyond Connected Veh