FAU Seminar

Control of Freeway Corridors: Objectives, Performance Measures, Strategies

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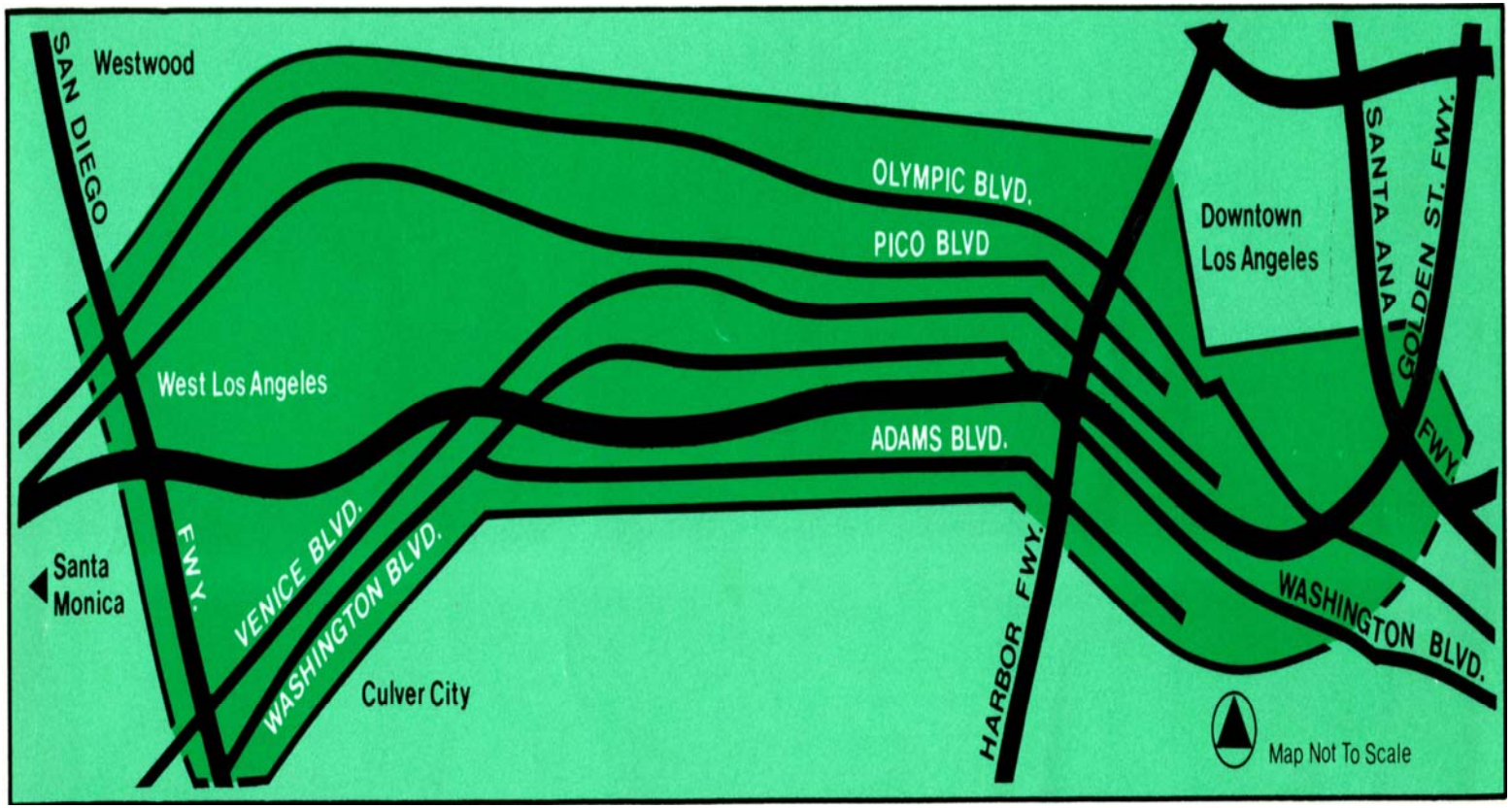
Outline

- **Integrated Corridor management**
  - **Background/Problem Statement**
  - **National Programs: ICM**
  - **Research Challenges/Opportunities**
- **Signalized Intersections: Performance Measurement**
- **Ramp Metering**
- **Freeway Arterial Coordination**
- **Looking Ahead**

Background: Corridor Management

Cooperative management of freeways and adjacent arterial networks

Los Angeles, Smart Corridor 1988

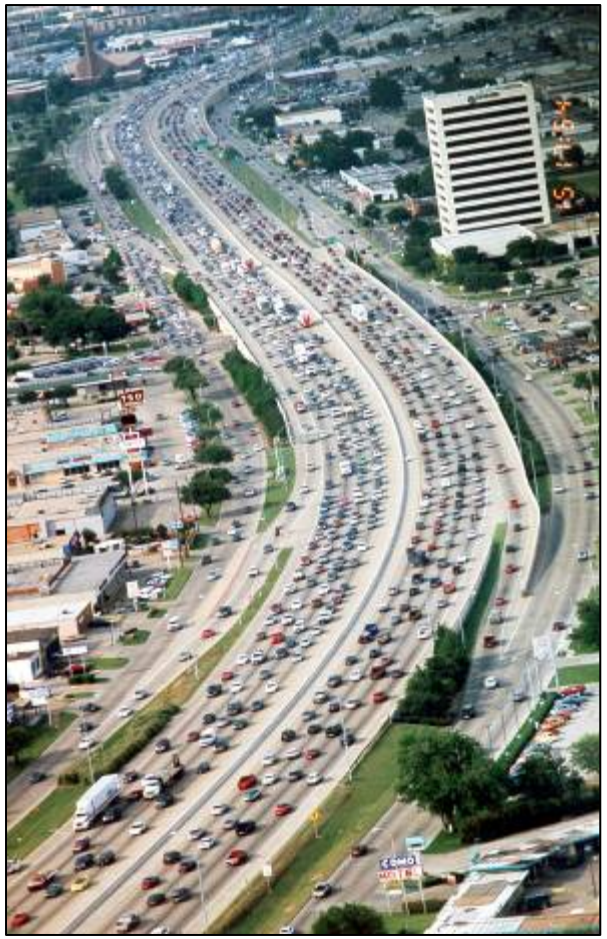


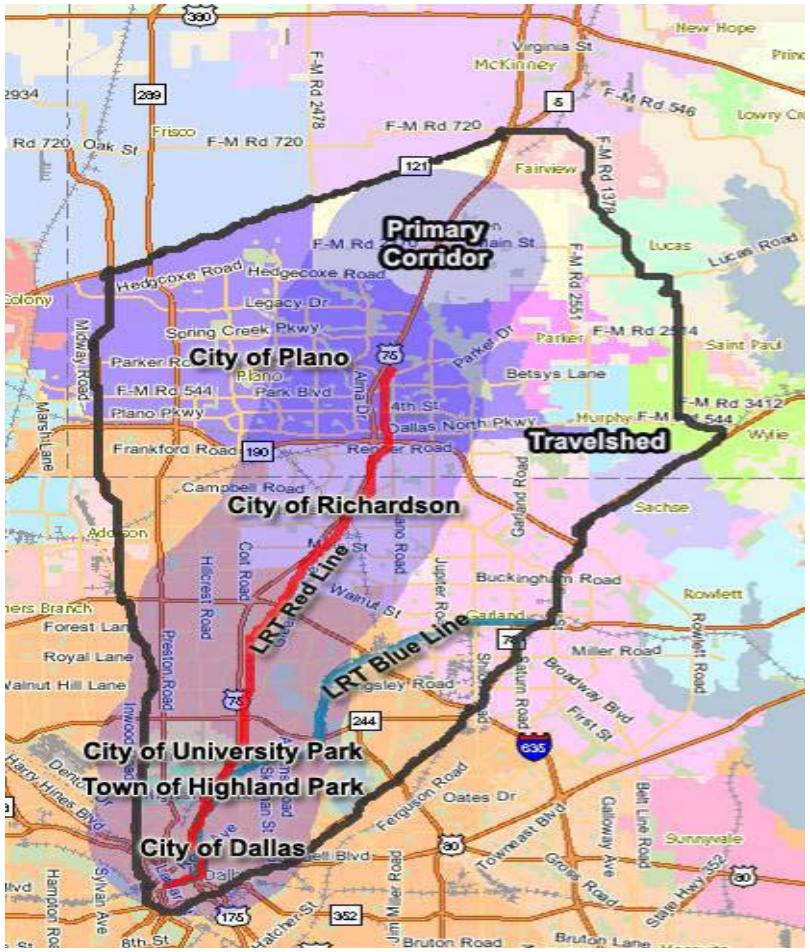
Background: Corridor Management

Corridor Traffic Management & Information Vision

USDOT ICM Program (1)

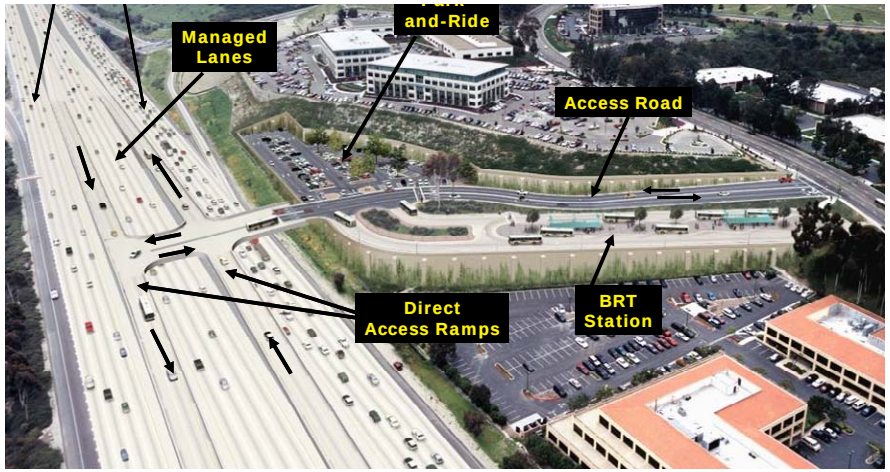
US-75 ICM Corridor, Dallas, TX

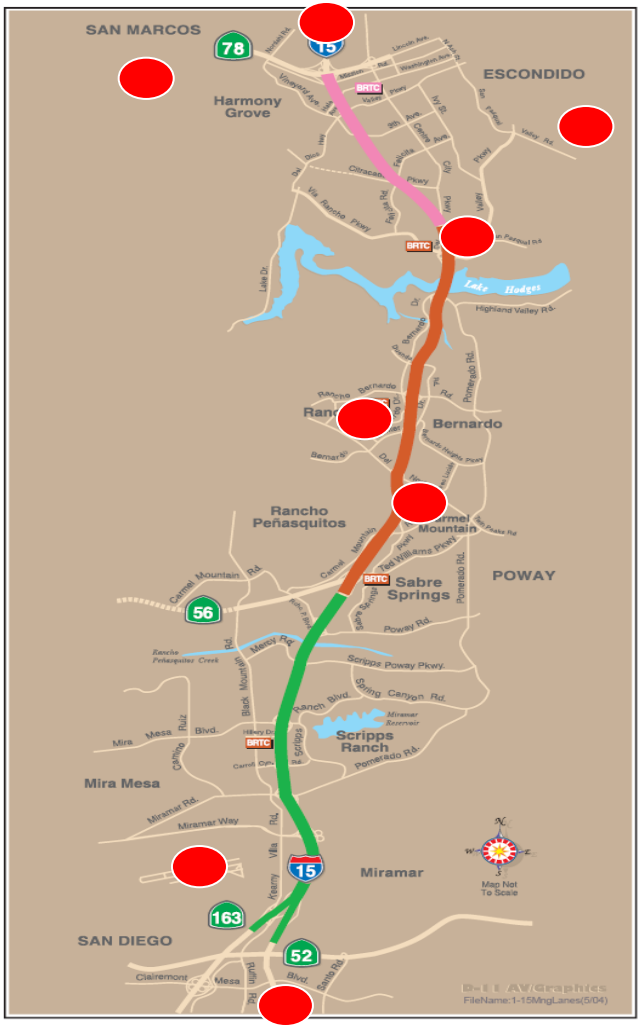




USDOT ICM Program (2)

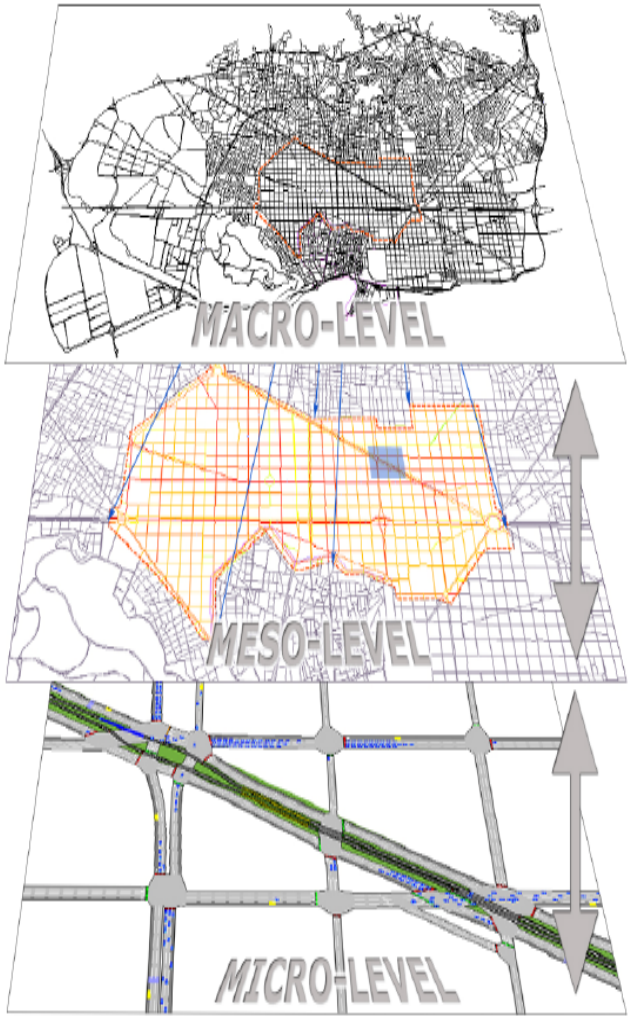
I-15 ICM Corridor, San Diego, CA





USDOT ICM Program (3)

Modeling Framework

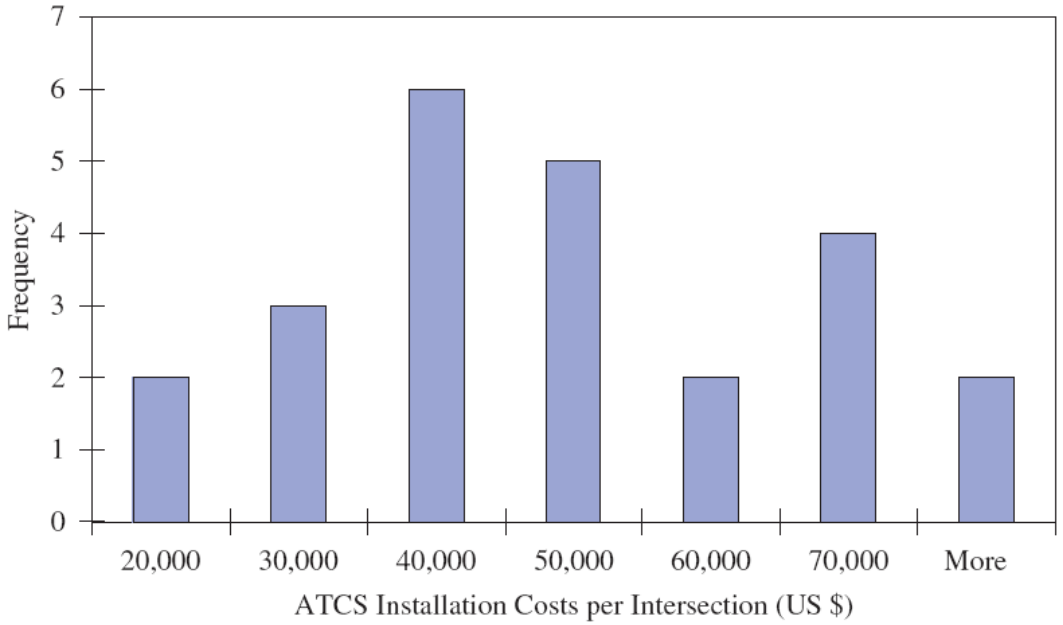


Findings

- **Delay reduction**
- **Travel time reliability improvement**
- **Fuel savings**
- **Emissions reduction**
- **Agency cooperation**
- **Decision support systems**

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

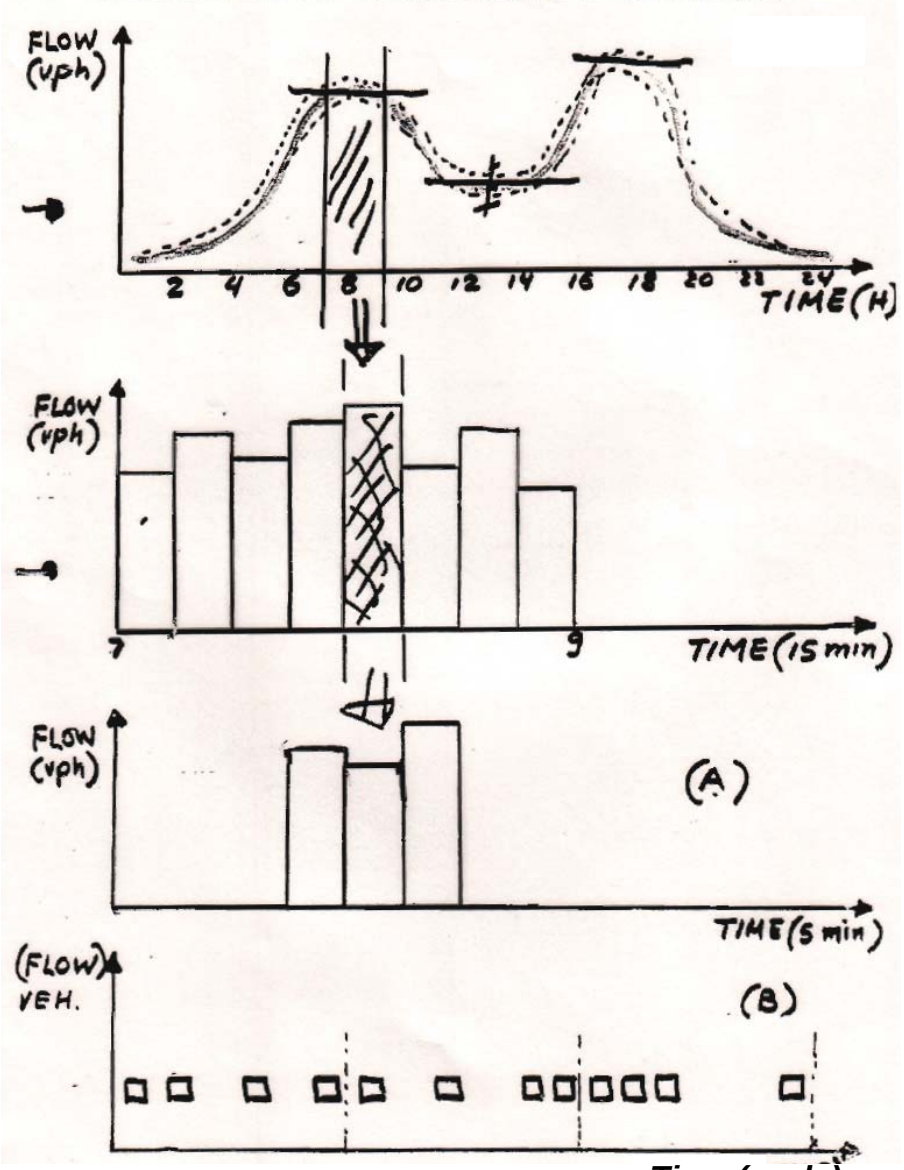
Traffic Flow Variability vs. Control

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

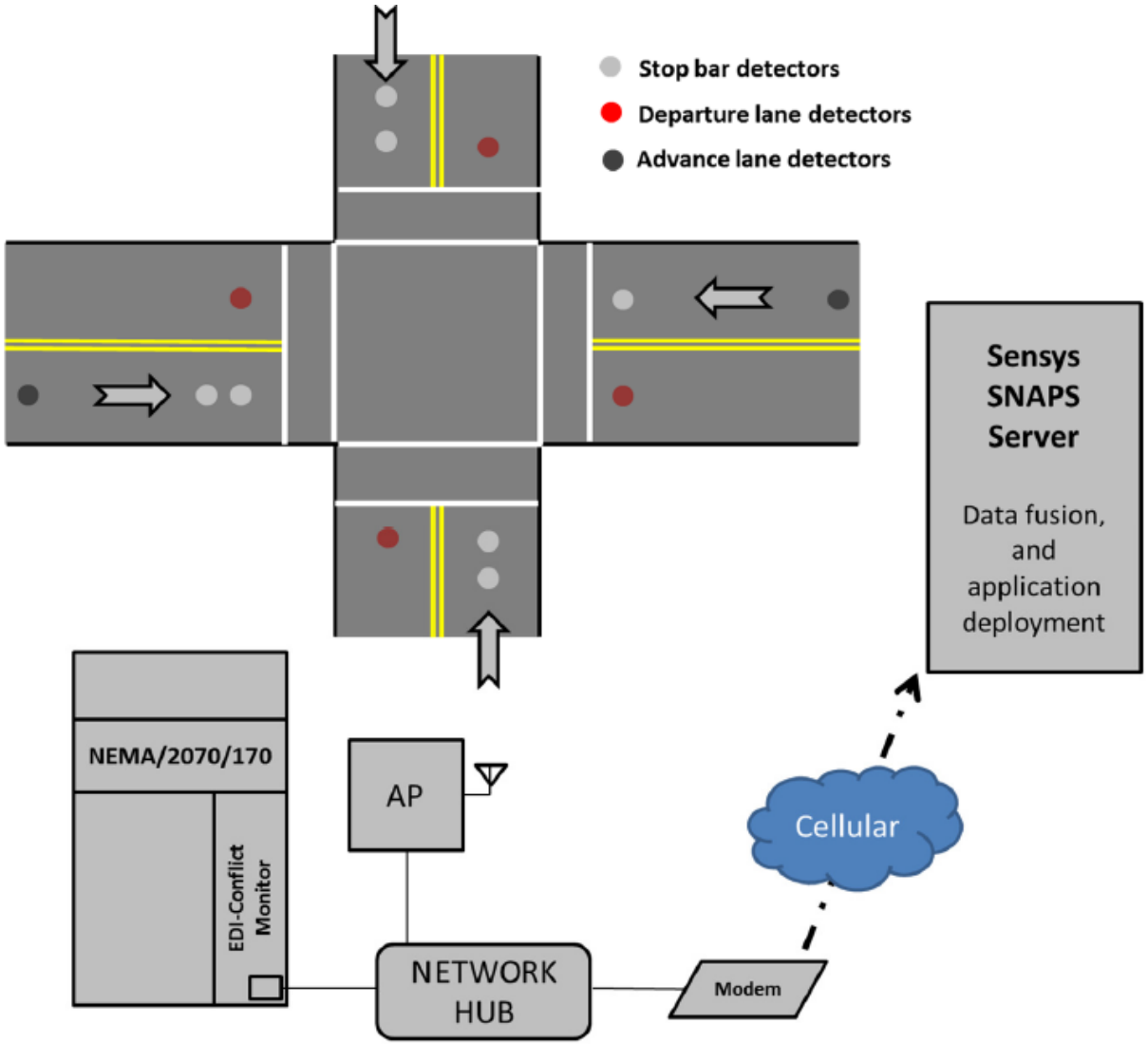
B
- Fixed time plans
- Traffic responsive plan selection
- System detection

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

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

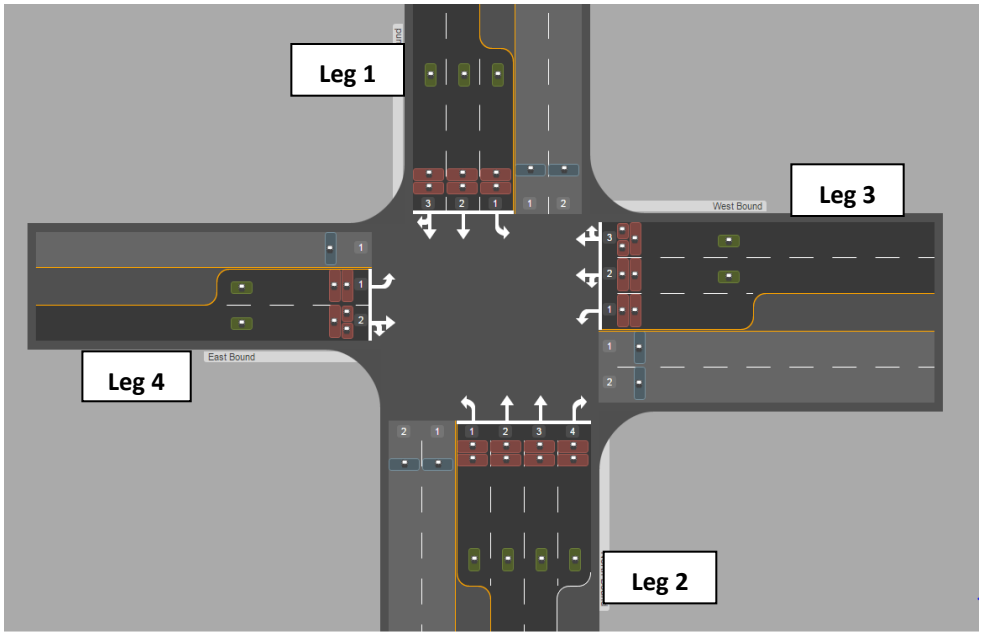


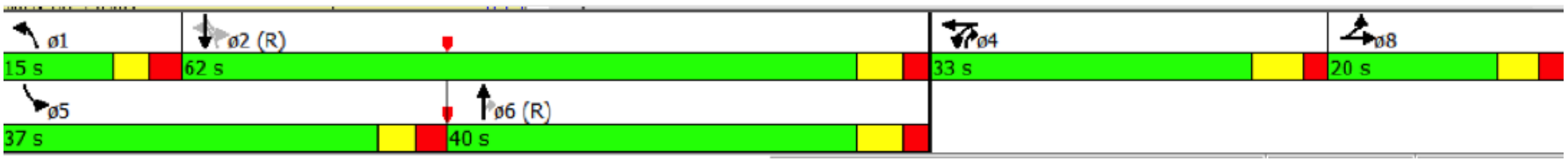
Data Collection System



SENSYS networks

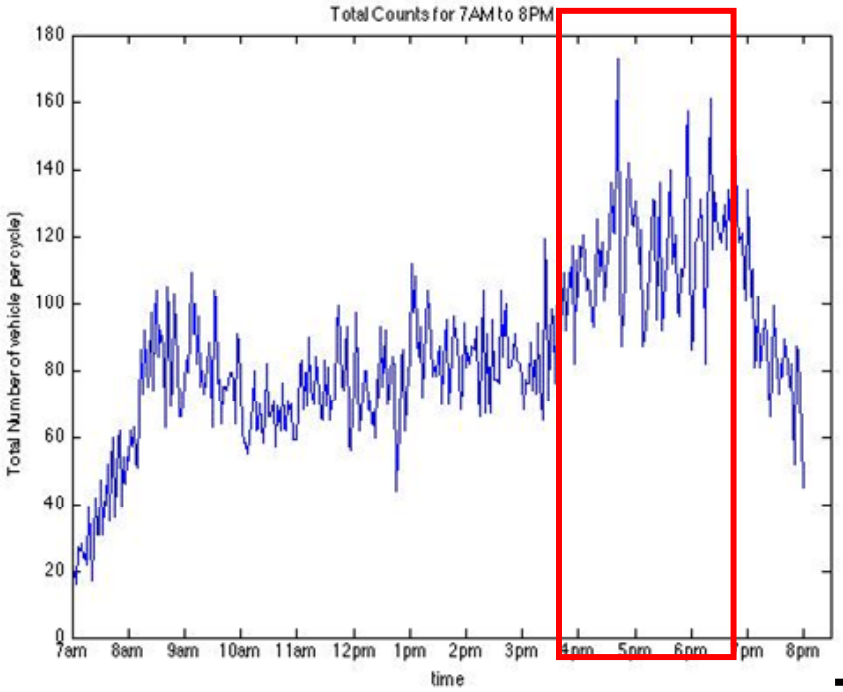
Selected Test Site: Beaufort, SC





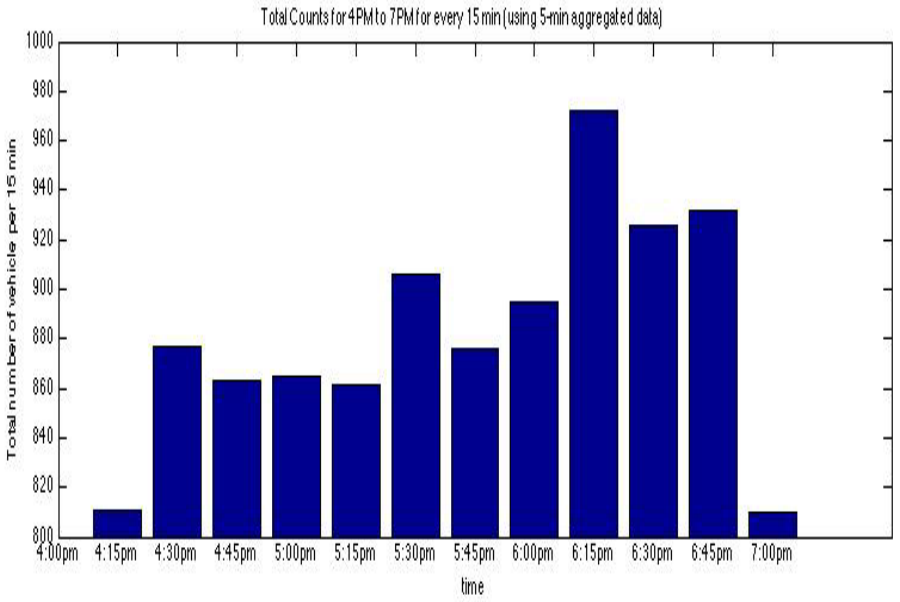
Daily Variation: Intersection Volume

February 28, 7AM to 8PM



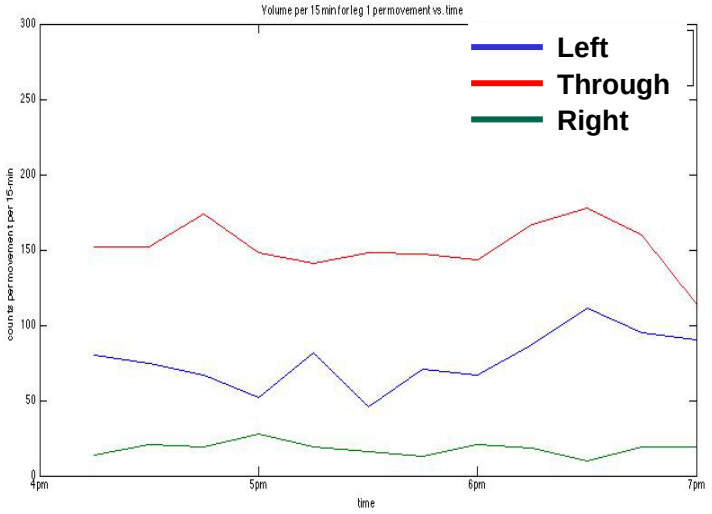
Total volume (veh/cycle)

Peak Period, 4-7 PM

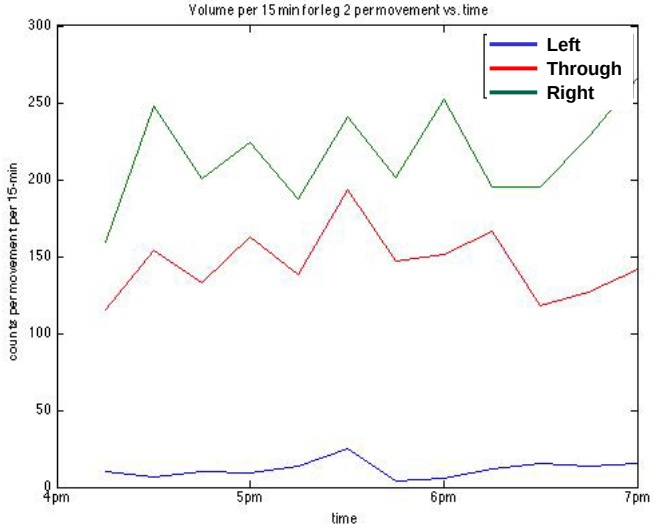


Total volume (veh/15 minutes)

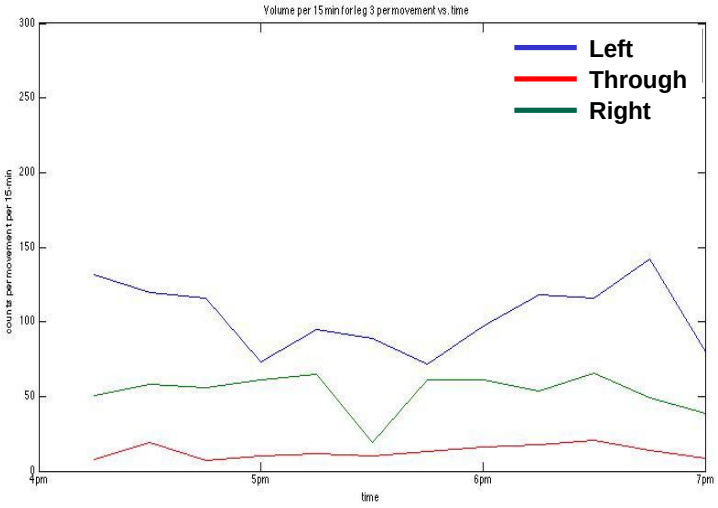
Peak Period 4-7 pm: Turning Movements



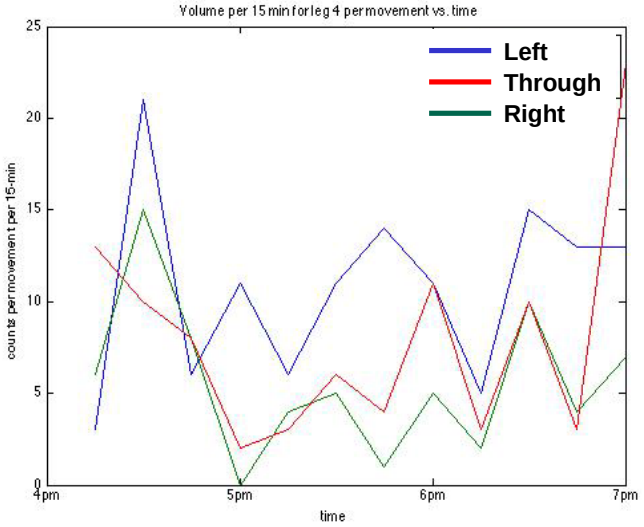
Leg 1



Leg 2

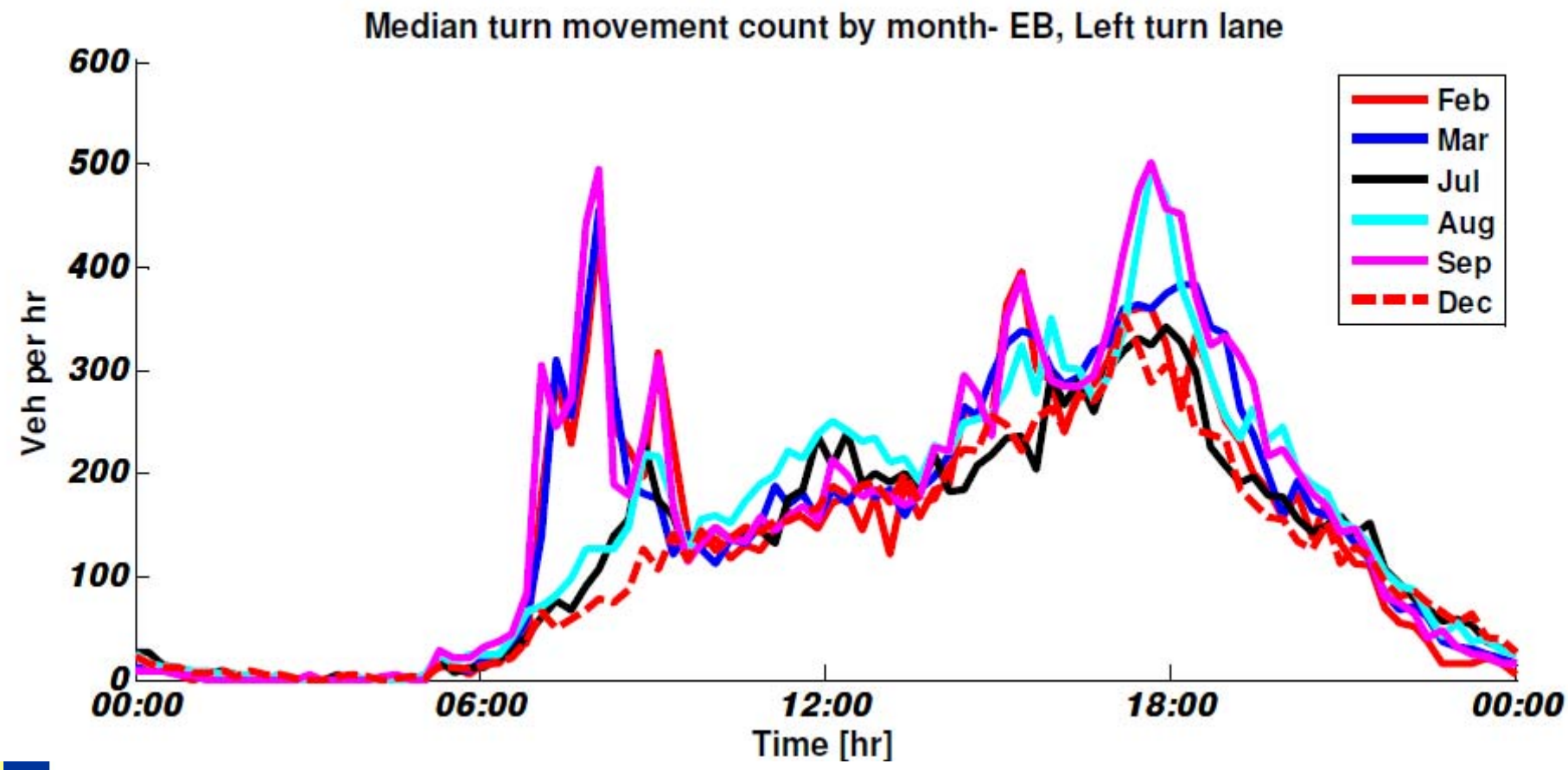


Leg 3



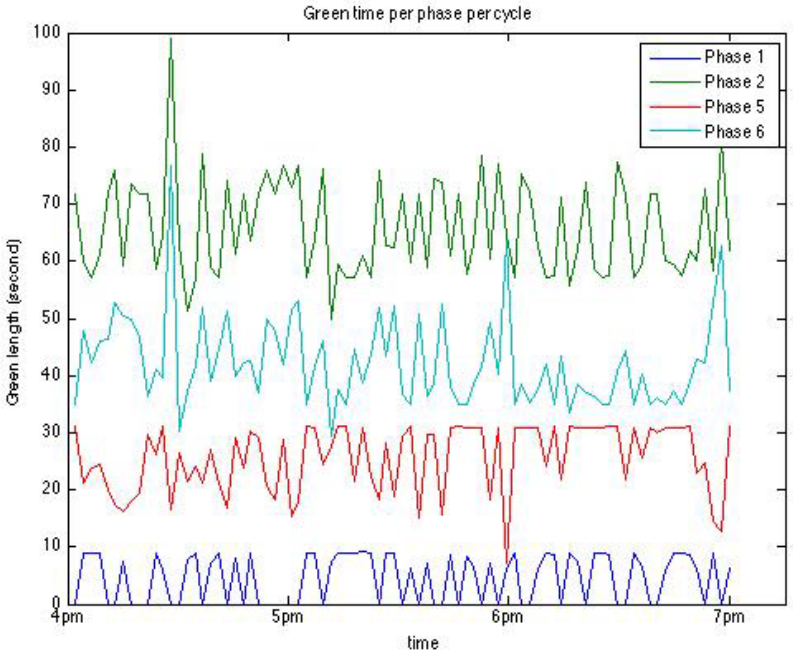
Leg 4

Seasonal Volume Variation

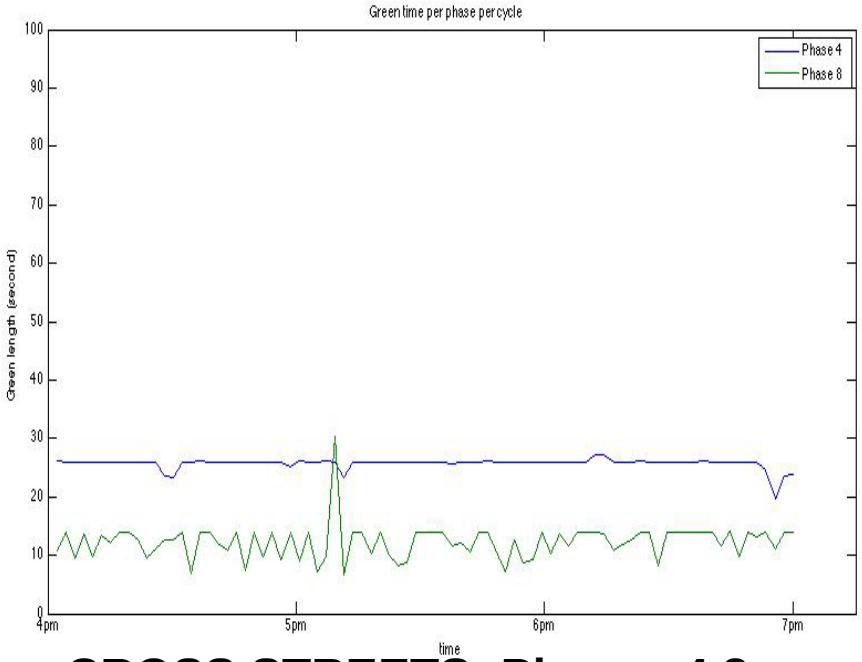


Signal Control Data

Green Times per Phase

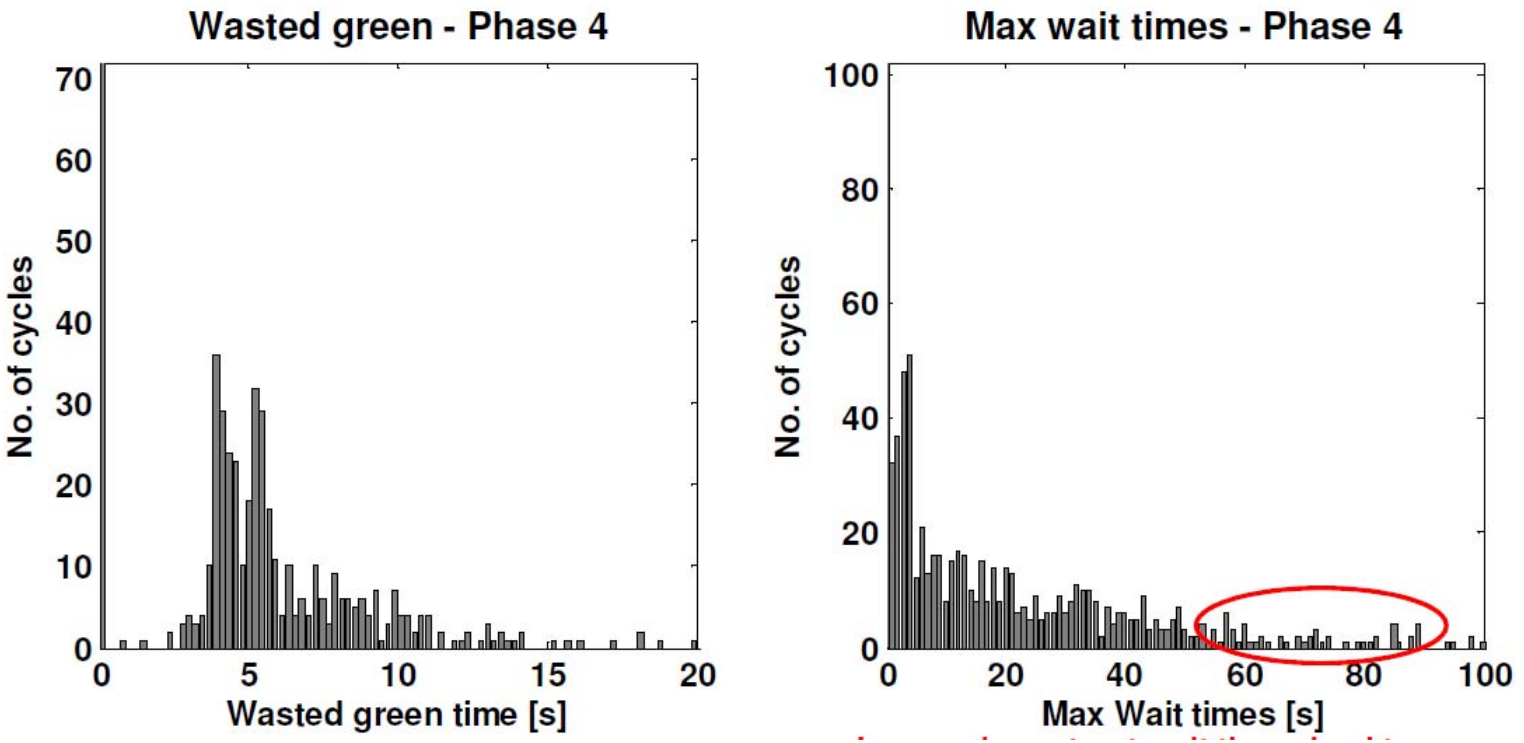


MAIN STREET: Phases 1,2,5,6



CROSS STREETS: Phases 4,8

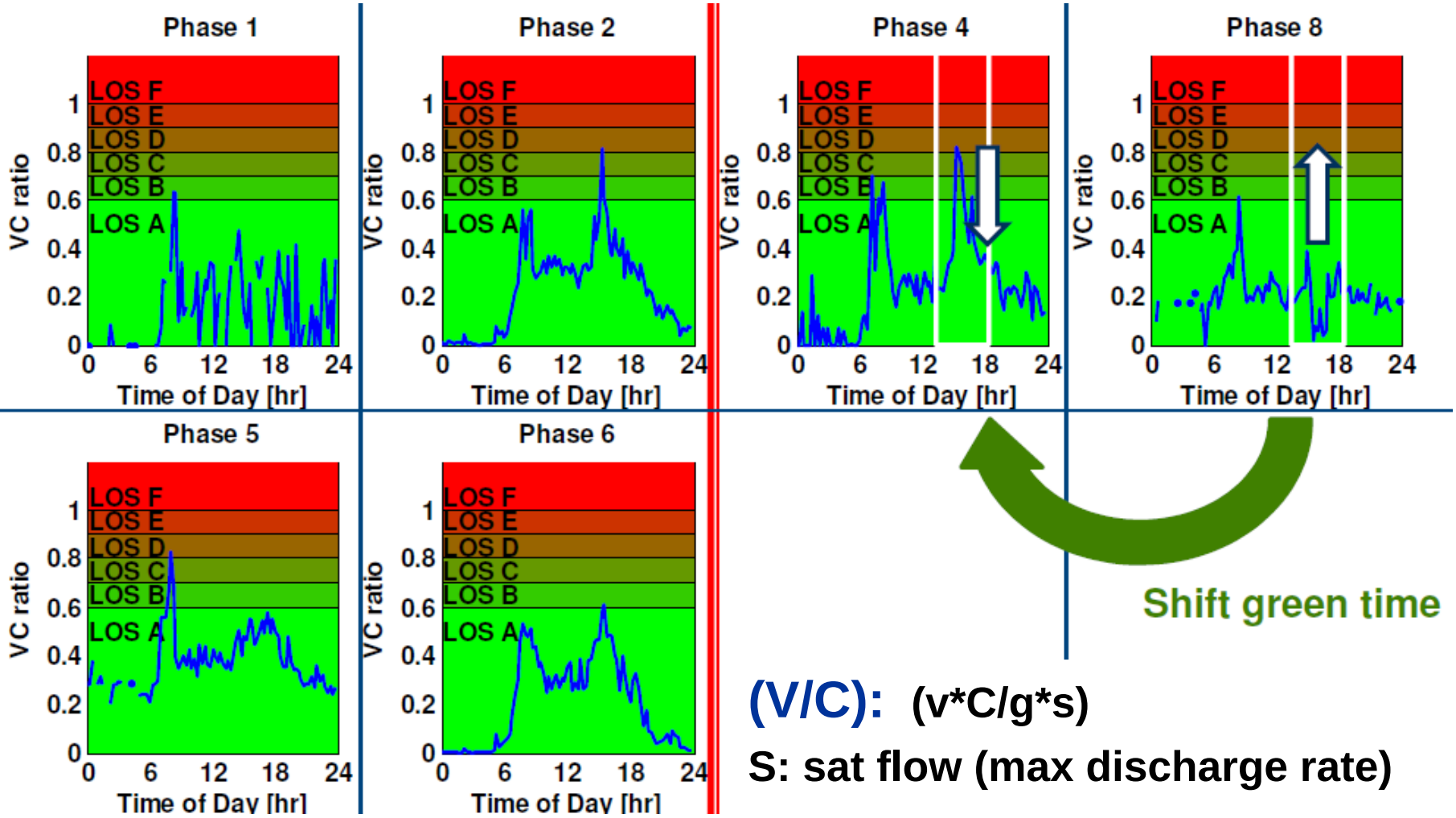
Signal Phase Operations



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

Max Wait time: Max time to receive green

Performance: V/C and LOS

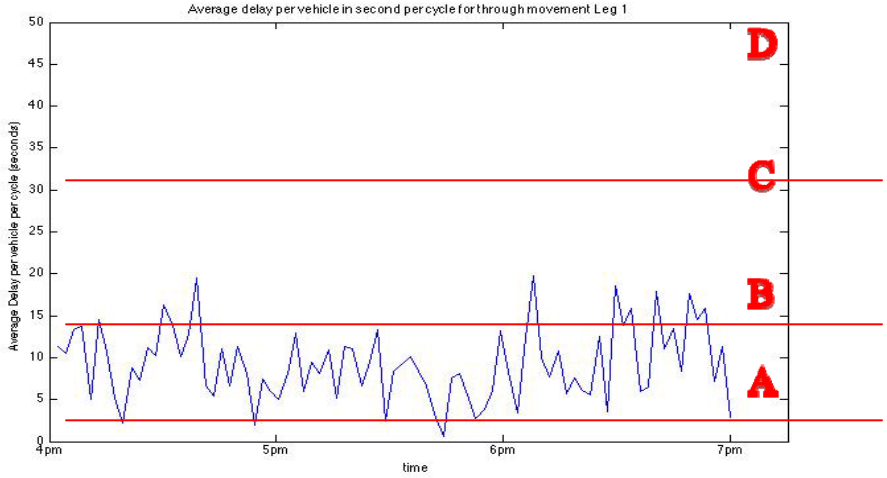


(V/C): (v*C/g*s)

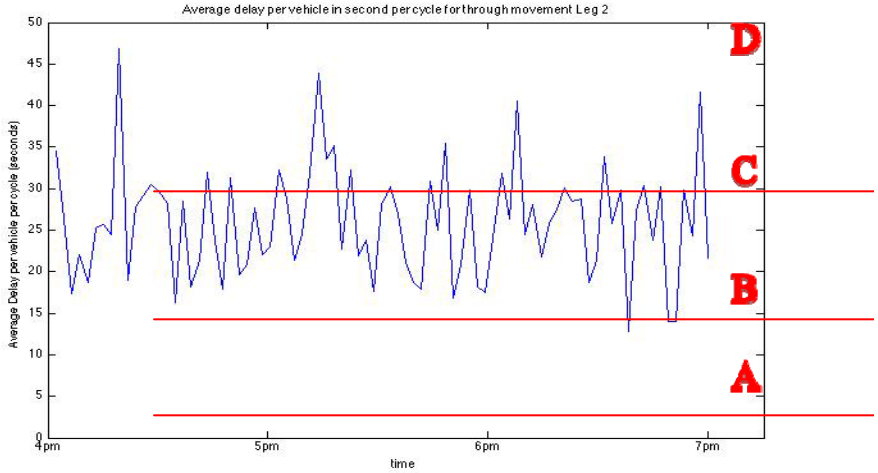
S: sat flow (max discharge rate)

LOS: Level of Service per HCM

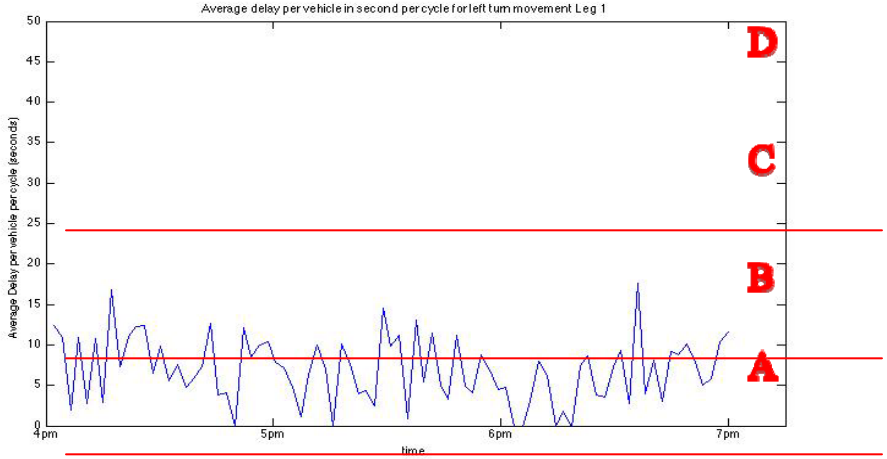
Average Delay (sec/veh)
HCM Level of Service (LOS)



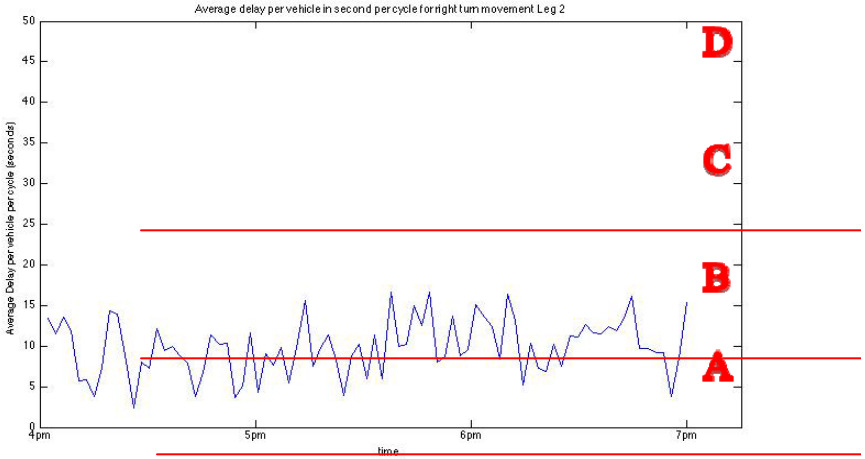
Through movement, Leg 1



Through movement, Leg 2



Left turn movement, Leg 1



Right turn movement, Leg 2

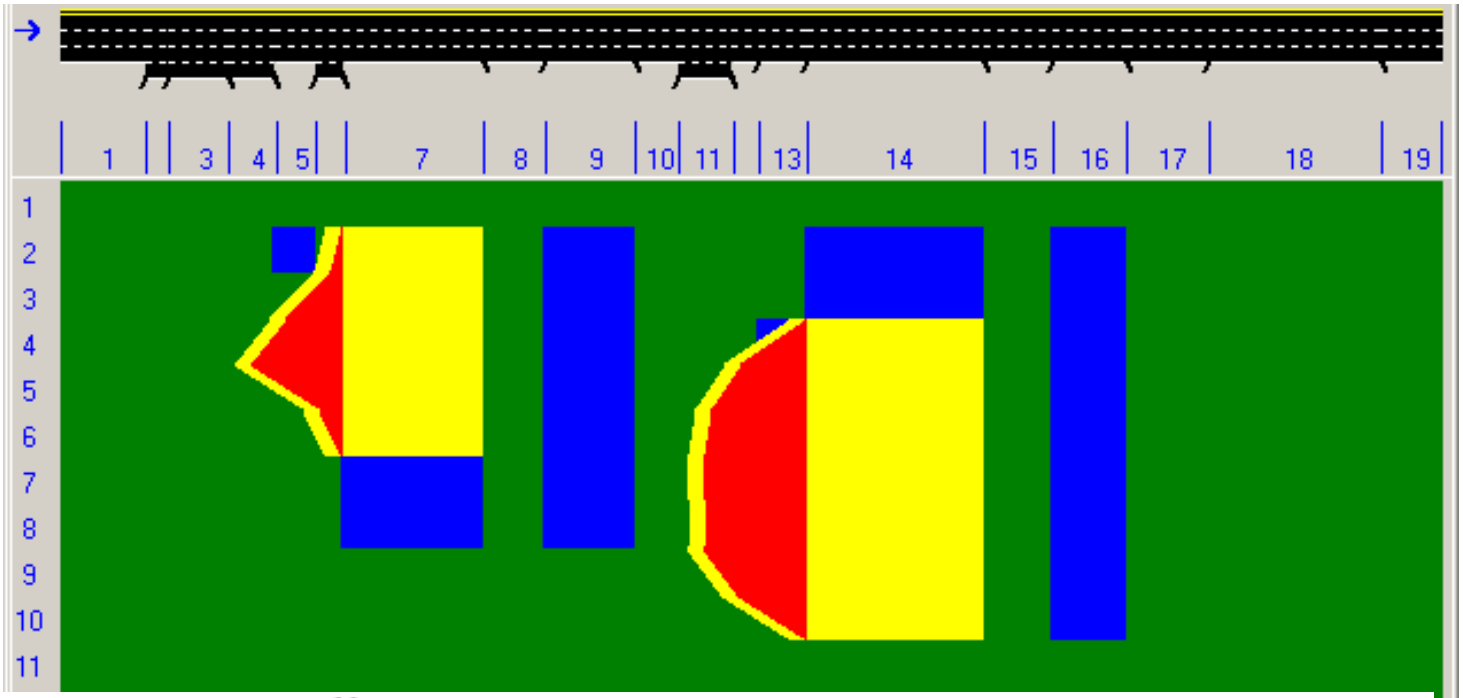
Summary

- Reliable data collection system
- Performance measures for travelers and operators
- Uses existing infrastructure
- No interference with controller operation

- Ongoing/Future Work
  - Safety
    - Red-light running
  - Traffic Volume Prediction
  - Robust Signal Timing Plans

II. Freeway Ramp Metering

Control on-ramp flows to preserve freeway capacity



$$MAX \sum_{i=1}^{N} X_i \qquad \sum_{i=1}^{N} a_{ij} X_i \leq c_j$$

X_i : input flow rate at on-ramp i , N : # on-ramps

a_{ij} : proportion of traffic entering on-ramp i going through section j

C_j : capacity of freeway segment j

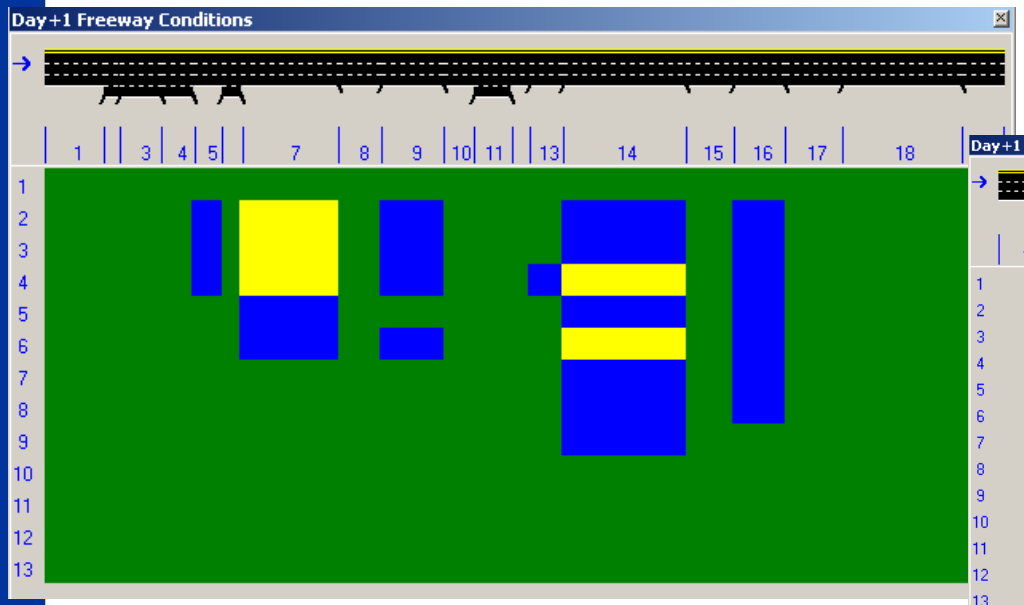
Freeway Ramp Metering: Issue

Issue

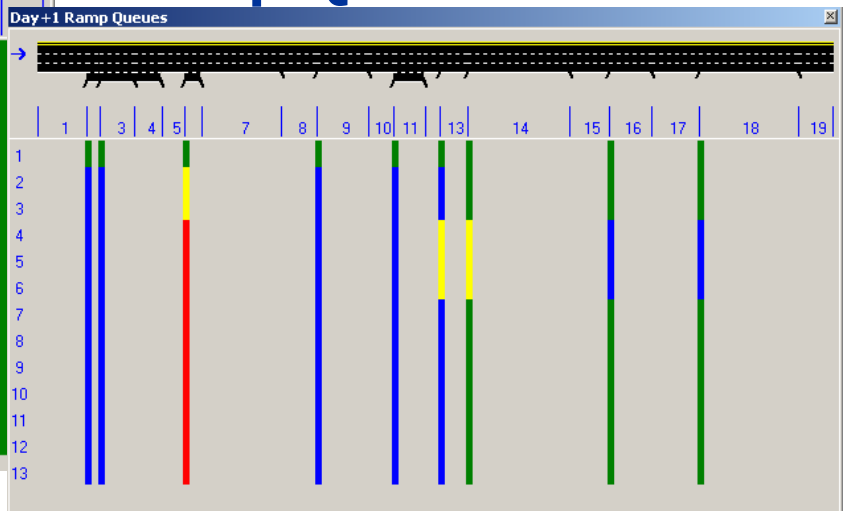
Limited Ramp Storage

- **Spillback to local street network**
- **Excessive delays**

Freeway Mainline



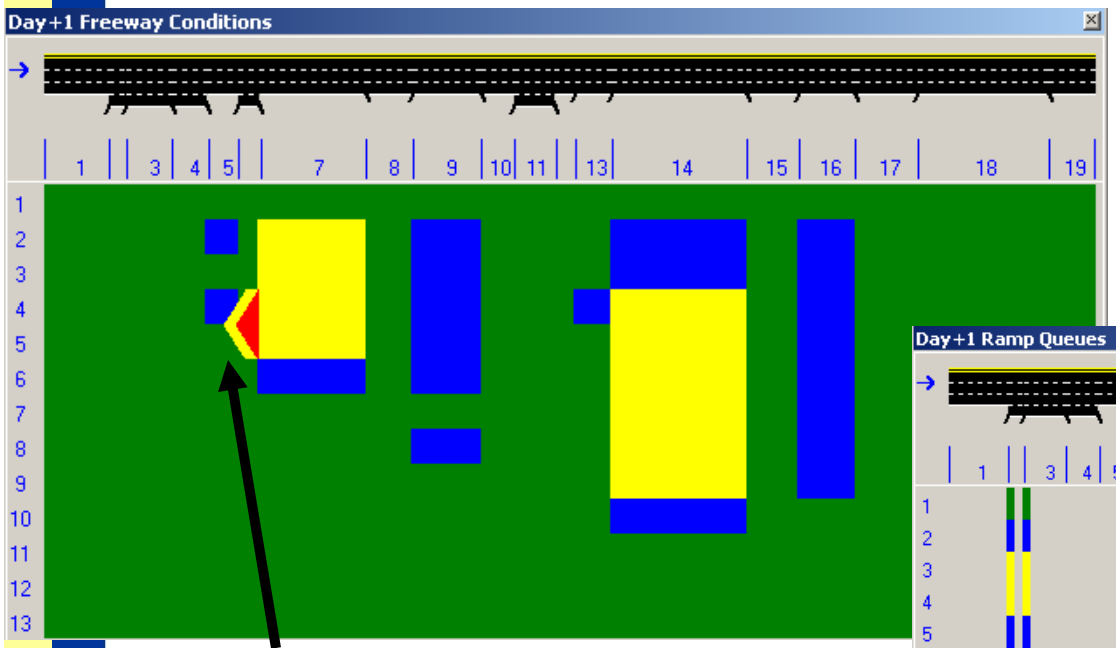
Ramp Queues



Example: Fixed-Time Metering (3)

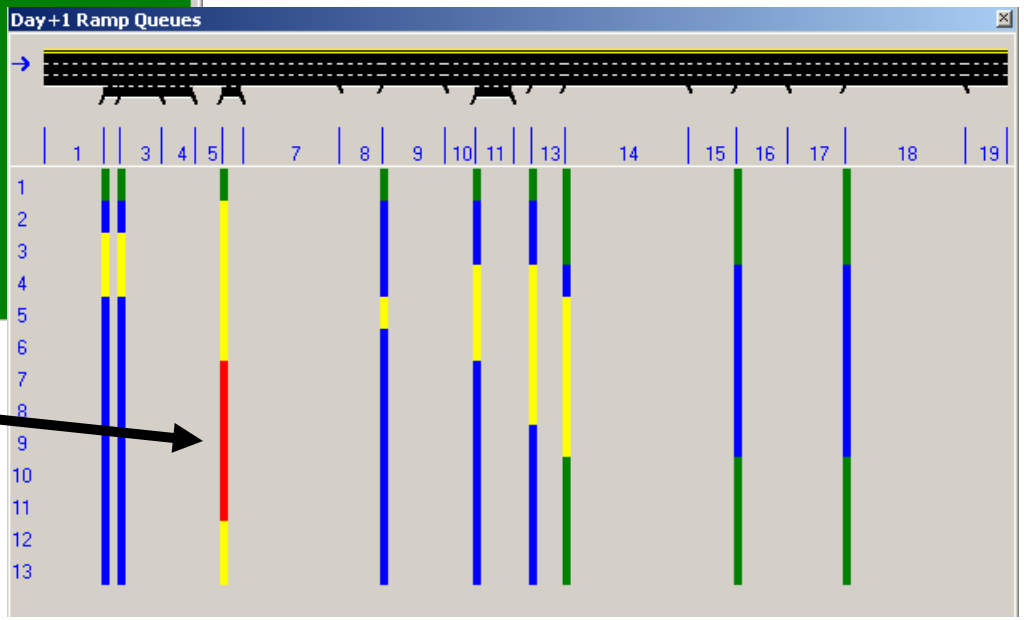
Ramp constraints: min on-ramp rates, max delays

Freeway Mainline



Queue Override

Ramp Queues



Trade-off:

Mainline Congestion vs. Ramp Queue

III. 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 field test results**

Freeway Arterial Coordination Handbook

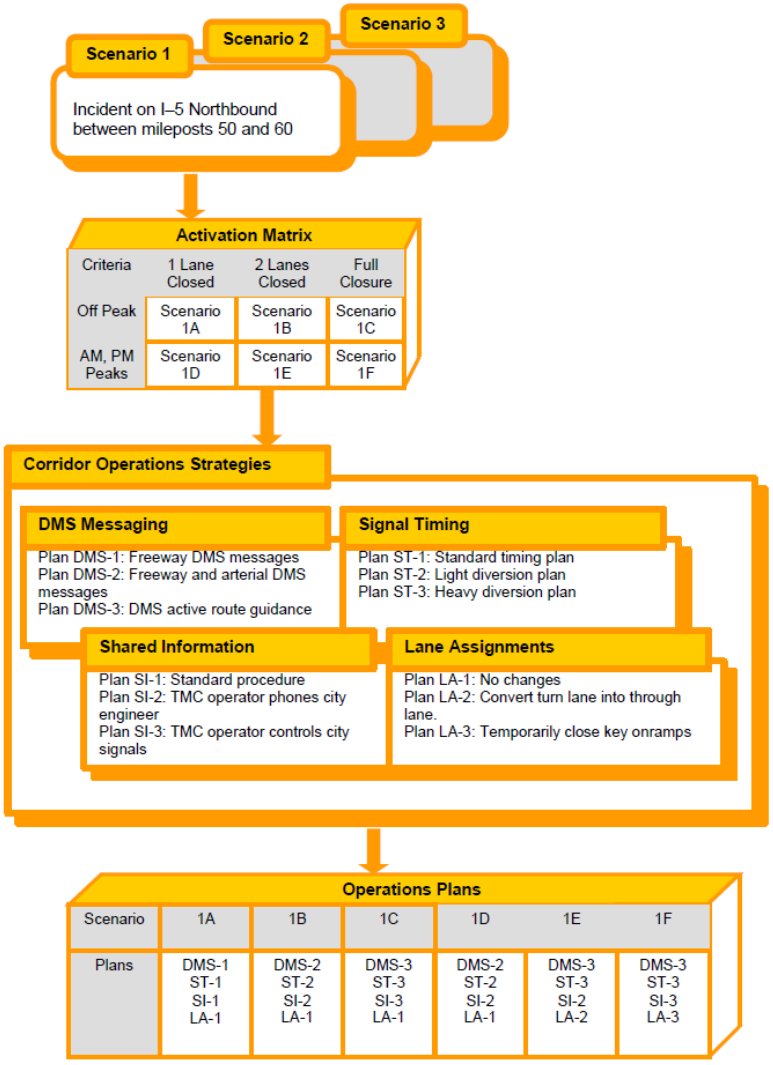
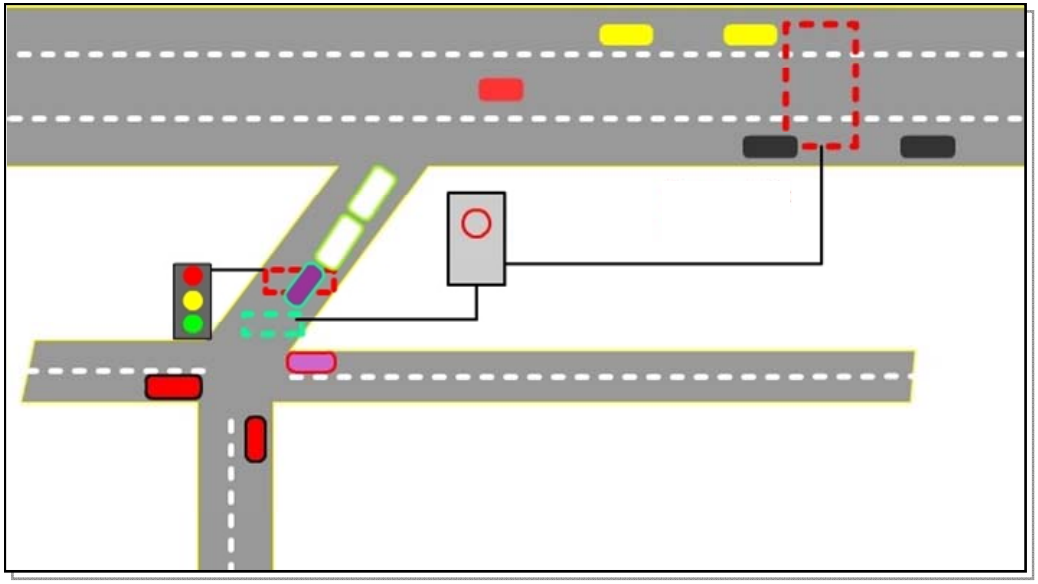


Figure 12. Chart. Example of development of corridor operations plans.

Proposed on-Ramp Access Control (1)

Determine the green times for the signal phase(s) serving the on- ramp direction to avoid queue spillover from ramp metering and result in queue override



Proposed on-Ramp Access Control (2)

Assumptions:

On-ramp is metered with ALINEA control strategy

There are k intersections on the arterial

Signals are coordinated with common cycle time C

Intersections are undersaturated

Objectives/Constraints:

Determine signal settings (green times & offsets)

Avoid on-ramp queue spillback

Serve the traffic demand on arterial phases

Arterial link storage (arterial spillback)

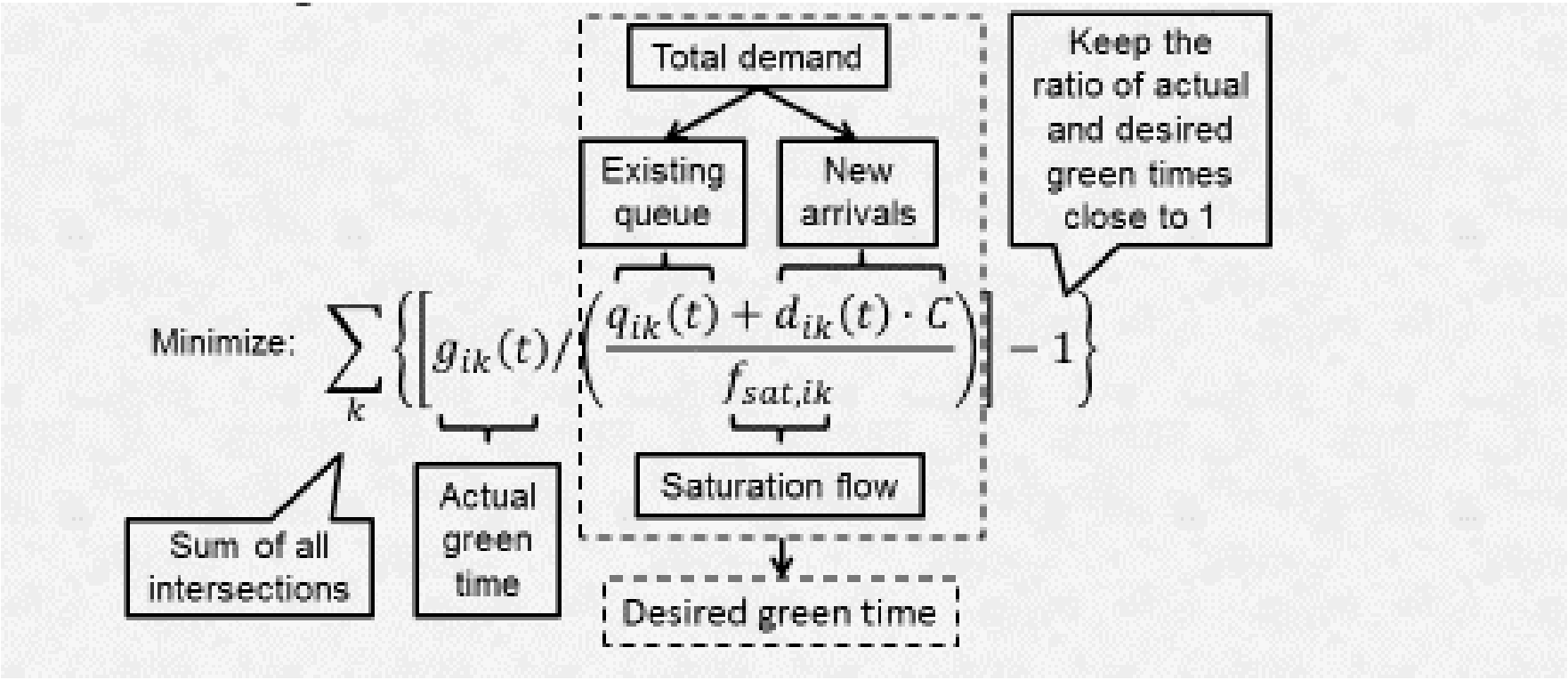
Minimum phase green times

Common fixed cycle length

Proposed on-Ramp Access Control (3)

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

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



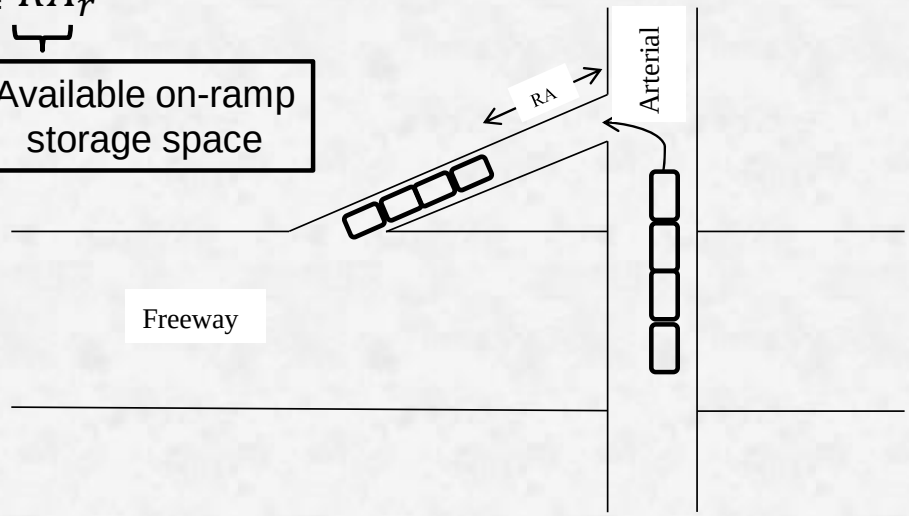
Proposed on-Ramp Access Control (3)

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:

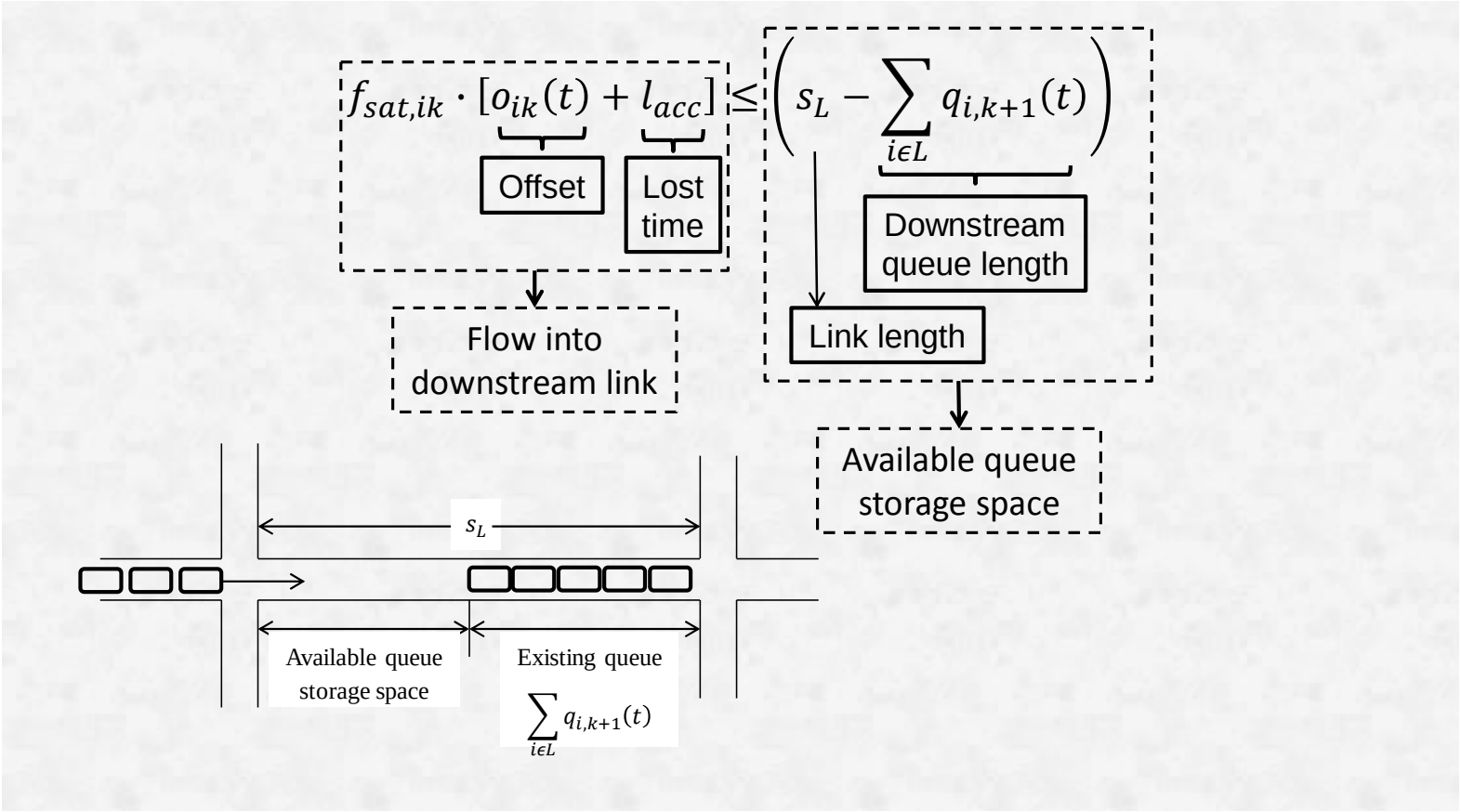
$$\underbrace{\sum_{i \in R} f_{sat,ik} \cdot g_{ik}(t)}_{\text{Phases for on-ramp access}} \leq \underbrace{RA_r}_{\text{Available on-ramp storage space}}$$

Total flow onto freeway on-ramp



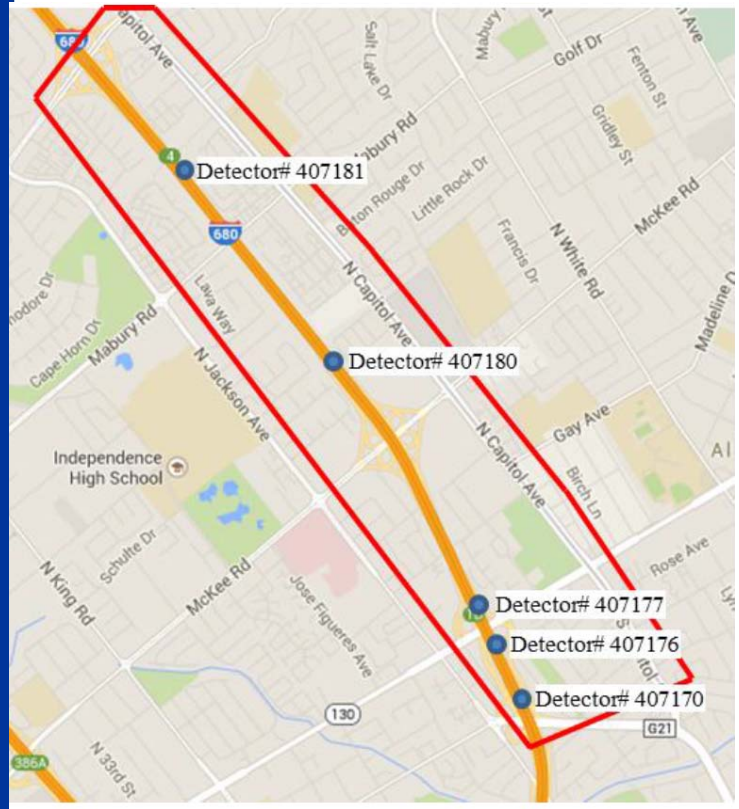
Proposed on-Ramp Access Control (4)

Constraint: Arterial link storage



Application

Test Site: I-680, San Jose CA



- **AIMSUN Microscopic Simulator**
- **API**

	Before	After	% Difference
Arterial Performance			
Average Delay on Parallel Arterial (min/veh)			
Capitol Ave NB	7.55	7.4	-1.95%
Capitol Ave SB	2.05	1.79	-12.73%
Arterial--Average Delay on Cross Street (sec/veh)			
Alum Rock WB	34.96	36.57	4.62%
Alum Rock EB	9.52	8.01	-15.88%
McKee WB	10.04	10.62	5.80%
McKee EB	2.03	1.34	-34.10%
Berryessa WB	9.95	11.23	12.86%
Berryessa EB	7.71	6.71	-12.86
Freeway Performance --VMT			
I-680 NB**	**13749.1**	**14220**	**3.4**

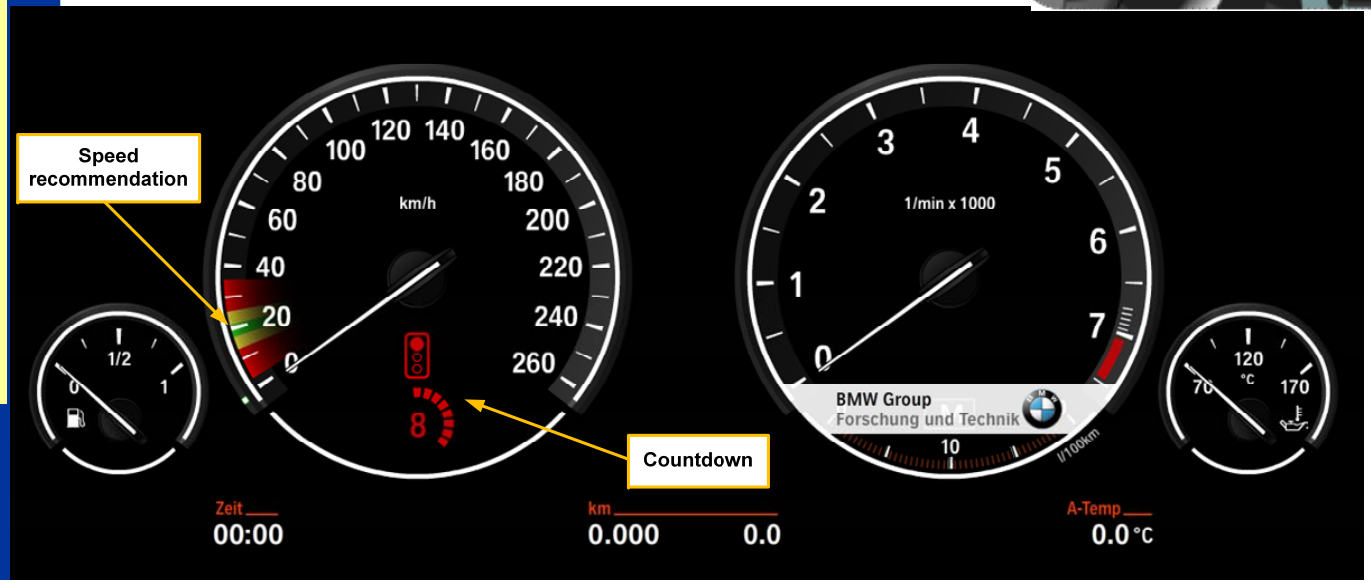
Looking Ahead: Connected Vehicles

"Here I am"

V2V and V2I

V2I Example: SPaT message

Application: Dynamic Speed Advisory (source: BMW)



Looking Ahead: Beyond Connected Veh