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Transportation  
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## **Using an ADUS to Compute and Visualize Performance Measures on Managed Facilities**

2<sup>nd</sup> International Symposium on Freeway and  
Tollway Operations

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## Performance on Managed Facilities is Important

- Statewide California wanted to allow single occupancy hybrid cars into the HOV lanes. Federal performance requirement:
  - HOV facilities need to maintain a minimum average operating speed 90 percent of the time over a consecutive 6-month period during morning or evening weekday peak hour periods

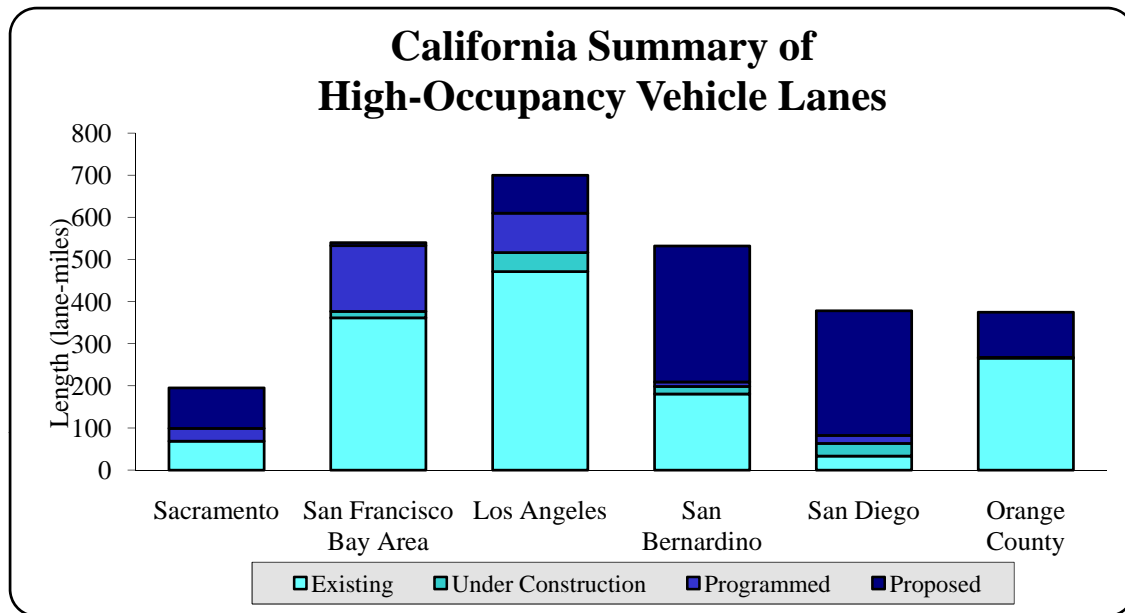
The state passed out 85,000 stickers. Now it has to monitor the performance of the facilities.

- In 2004 SANDAG (San Diego MPO) convinced voters to approve a half-cent sales tax for transportation projects, \$14B, mostly for additional HOV lanes. It has promised (Independent Taxpayers Oversight Committee, ITOC) to monitor the facilities that it's building to ensure that they are operating efficiently.

### Key:

- Additional pressure to explain performance

# Caltrans HOV Facilities: 80 facilities in State



## SUMMARY OF HIGH-OCCUPANCY VEHICLE LANES

District	Region	Length (lane-miles)			
		Existing	Under Construction	Programmed	Proposed
3	Sacramento	68.6	0	30.6	96.2
4	San Francisco Bay Area	361.4	15.2	156.3	7.3
7	Los Angeles	471.4	45	93.7	89.8
8	San Bernardino	180.8	18	10.4	322.8
11	San Diego	33.24	30	19.2	296
12	Orange County	265.9	1.8	0	107.2
<b>Statewide Total</b>		<b>1381.34</b>	<b>110</b>	<b>310.2</b>	<b>919.3</b>

# Current Practices: Yearly HOV Facility Report

Many different types of information in the yearly HOV reports:

- Descriptions of facilities
- Configuration of each facility (on-ramps, off-ramps, etc).
- History of construction, funding
- Limited performance reporting:
  - Peak traffic volumes on each facility
  - Peak travel time savings on each facility
  - Maps showing congestion locations

## HOV LANE PEAK HOUR VOLUMES

			A.M. Peak Hr (veh)	P.M. Peak Hr (veh)
ALA-80	WB	Bay Bridge Toll Plaza	3730	1057
ALA-80	WB	Contra Costa County Line to Powell St	1698	689
	EB	Powell St to Contra Costa County Line	199	1070
ALA-84	WB	Dumbarton Bridge Toll Plaza	1229	354
ALA-92	WB	San Mateo Bridge Toll Plaza	839	492
ALA-680	SB	Route 84 to Route 237 Calaveras Blvd.	420	N/A
ALA 880	SR	Marina Blvd to Whipple Road	1196	1780

## Travel Time Data (HOV Lane Time Savings)

ROUTE	LIMITS	LENGTH	PEAK DIRECTION	TRAVEL TIME		HOV LANE TIME SAVINGS
				Mixed Flow	HOV	
10 / San Bernardino Freeway	Alameda to Route 605	13.8 mi.	Westbound (AM)	35 min. - 18 sec.	16 min. - 31 sec.	19 minutes *
		14.0 mi.	Eastbound (PM)	36 min. - 20 sec.	19 min. - 30 sec.	17 minutes *
	Route 57 to S.B. Co. Line	5.4 mi.	Westbound (AM)	05 min. - 36 sec.	04 min. - 27 sec.	02 minutes *
		5.9 mi.	Eastbound (PM)	07 min. - 47 sec.	01 min. - 40 sec.	02 minutes *
14 / Antelope Valley Freeway	Route 5 to Pearblossom	27.9 mi.	Southbound (AM)	28 min. - 26 sec.	25 min. - 19 sec.	04 minutes ****
		26.5 mi.	Northbound (PM)	32 min. - 44 sec.	24 min. - 13 sec.	09 minutes ****
57 / Orange Freeway	Route 60 to Orange Co. Line	3.4 mi.	Southbound (AM)	14 min. - 21 sec.	05 min. - 17 sec.	10 minutes
		3.6 mi.	Northbound (PM)	15 min. - 10 sec.	13 min. - 34 sec.	02 minutes
60 / Pomona Freeway	Brea Canyon to S.B. Co. Line	5.6 mi.	Westbound (AM)	15 min. - 09 sec.	09 min. - 41 sec.	06 minutes
		5.9 mi.	Eastbound (PM)	06 min. - 13 sec.	04 min. - 50 sec.	02 minutes

# Current Practices: Performance Reporting

## Issues:

### 1. Reporting takes forever

- It's done as a yearly report, takes many months to produce

### 2. Reported measures don't completely capture what's going on

- Eg: Is the travel time difference constant for the entire day? Or does it vary by time of day?
- Eg: What if both the HOV and ML facilities are congested? What is travel time difference actually telling you?

### 3. Can't compare across facilities

- Since each district reports different numbers, they can't be compared
- It is difficult to answer the question, "Compared to other facilities, are we managing this specific HOV facility properly?"

### 4. No ability to monitor according to federal standards

- They aren't monitoring continuously

### 5. No linkage from performance results to actions

- The measures that they are looking at aren't suggesting any management actions

# Project: Automate HOV Performance Reporting

## Goals of Project:

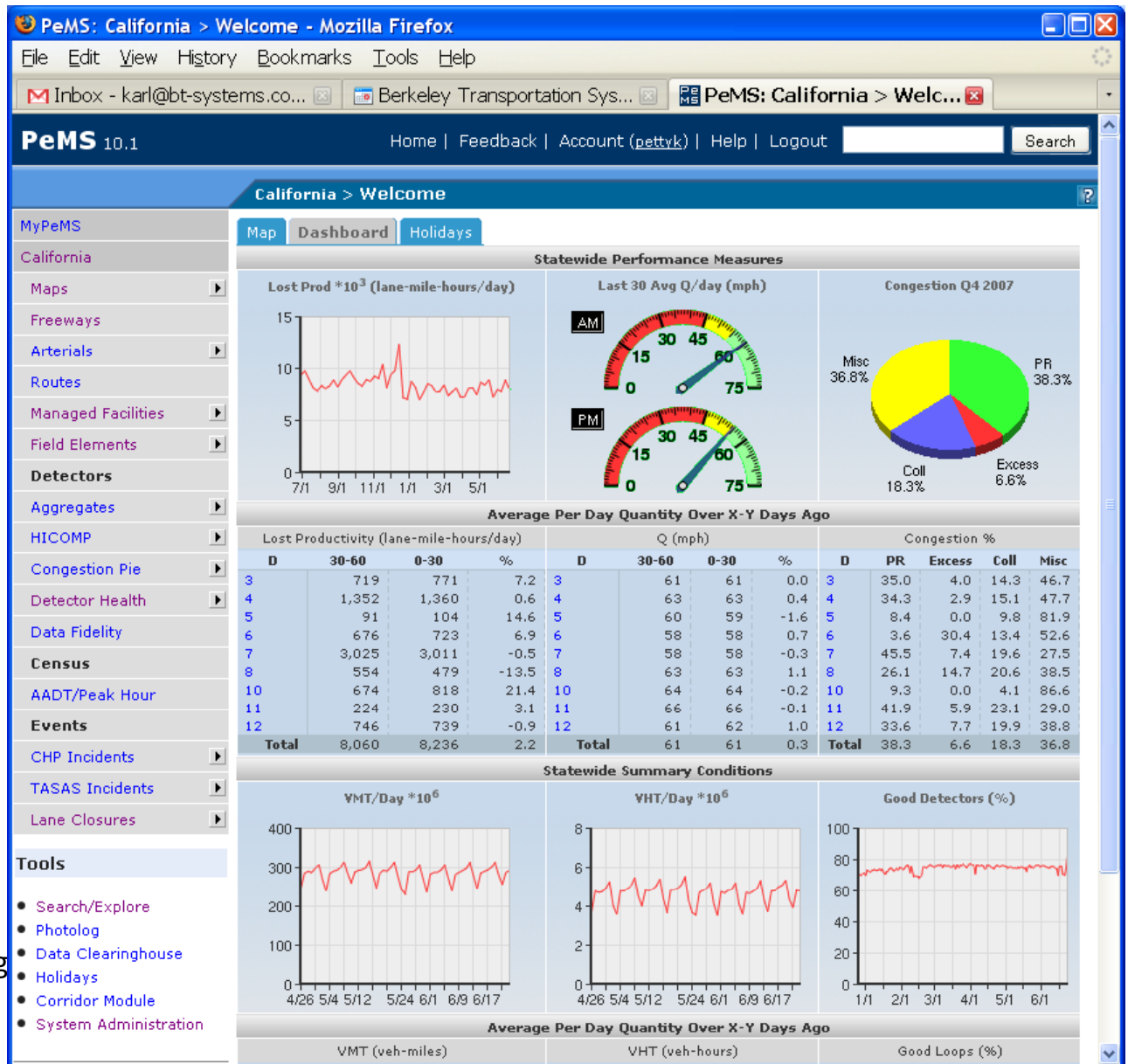
1. Extend and automate the reporting of HOV facility performance across the state (and do it in real-time).
2. Provide uniform reporting of HOV performance measures.
3. Provide the ability to highlight historical trends.
4. Link performance measures to management actions.

## Approach:

- Enhance the Freeway Performance Measurement System (PeMS) to provide focus on HOV facilities
- Extend PeMS with new measures to help management actions

# What is PeMS?

- Real-time Archive Data Management System (rt-ADMS)
- Collects many types of detailed, raw data in real-time and in batch mode
  - Fixed location, real-time ITS detectors
  - Tag data: toll tags, bluetooth
  - Traditional traffic count data: Census, WIM, AVCS
  - Incident data
  - Planned lane closures
- It processes the ITS data in real-time:
  - Diagnostics
  - Imputation for missing values
  - Speed calculations (if needed)
  - Rollup over space and time
  - Computes many performance measures (travel time, delay, etc).
- Large number of plots, charts, etc.
- Caltrans deployment:
  - Almost 27,000 sensors reporting every 30 seconds
  - Started in 1999, ~12TB of data



## Enhance PeMS with a Managed Facility focus (engineering)

1. Provided an easy way to navigate to HOV-specific performance reports for a single facility
  - Display facilities in tables that allow for organization of reports
2. Implemented all the standard performance reports
  - Provide reports on all standard measures: Delay, VMT, VHT, Q, Travel Times, Travel Time Variability
  - All for plots versus Time, Time of Day, Day of Week, and aggregations over time
3. Implemented federal reports on single facilities
  - Percentage of time in congestion, percentage utilization
4. Implemented easy HOV/Mainline Performance Comparisons
  - Compare HOV/ML quantities down the freeway at one point in time
  - Compare performance measures over time
  - Simultaneous travel time comparisons
5. Develop new measures and new visualizations that link results to management actions

# Managed Facility Listing Pages – Statewide

- The *Managed Facilities* section at the statewide level
- This is the jumping off point for managed facilities reporting
- Developed database schema to store all facility information
- Users can now see performance tables across the state for aggregated values (delay) and travel time

The screenshot shows the PeMS UCB Development web application interface. The main content area displays the 'California > Managed Facilities' page. It features a navigation menu on the left with categories like MyPeMS, California, Maps, Freeways, Arterials, Routes, Managed Facilities, Field Elements, Detectors, Aggregates, HICOMP, Congestion Pie, Detector Health, Data Fidelity, Census, AADT/Peak Hour, Events, CHP Incidents, TASAS Incidents, Lane Closures, and Tools. The main content area includes a 'Listing' tab, a summary table of lane-miles by district, a bar chart, and a detailed table of all facilities.

District	Open	Construction	Proposed	Total
03 - North Central	67.8	5.8	159.0	232.6
04 - Bay Area	311.8	40.1	123.0	474.8
07 - LA/Ventura	476.6	18.9	250.5	746.1
08 - San Bernardino/Riverside	155.5	18.6	335.0	509.1
11 - San Diego/Imperial	54.4	0	220.5	274.9
12 - Orange County	237.1	1.8	0	238.9
<b>Totals</b>	<b>1,303.1</b>	<b>85.2</b>	<b>1,088.1</b>	<b>2,476.3</b>

Facility	Dist	State	Fwy-Dir	From	To	Description	Lanes	Lane Miles	Access
D3: I-5	3	Proposed	I5-N	SAC 12.0	SAC 16.1	Laguna Blvd to Pocket Rd	1	4.1	
	3	Proposed	I5-N	SAC 23.8	SAC 32.7	I St to Airport Blvd	1	8.9	
	3	Proposed	I5-N	SAC 16.1	SAC 23.8	Pocket Rd to I St	1	7.7	
	3	Proposed	I5-S	SAC 23.8	SAC 16.1	I St to Pocket Rd	1	7.7	
	3	Proposed	I5-S	SAC 32.7	SAC 23.8	Airport Blvd to I St	1	8.9	
	3	Proposed	I5-S	SAC 16.1	SAC 12.0	Pocket Rd to Laguna Blvd	1	4.1	
D3: US-50	3	Proposed	US50-E	ED R3.2	ED R8.6	Bass Lake Rd to Ponderosa Rd	1	5.1	
	3	Proposed	US50-E	SAC 0.2	ED R2.9	ED Hills Blvd/Latrobe Rd to Bass Lake	1	2.7	
	3	Open	US50-E	SAC 12.5	SAC 0.8	Sunrise Blvd to Prairie City Road to El Dorado Hills Blvd/Latrobe Rd.	1	11.4	HOV
	3	Proposed	US50-E	ED R8.6	ED R12.2	Ponderosa Rd to Greenstone Rd	1	3.6	
	3	Proposed	US50-E	SAC	SAC	Watt Ave to Sunrise Blvd OC	1	7.5	

# Managed Facility Maps – Explore

- Standard integration with maps
- Overlaying the status of the facility (active, construction, programmed) with sensors
- Here we're painting the Census Traffic Counting Stations on the map
- Little popups show the occupancy requirements for the facility

The screenshot shows the PeMS 10.1 web application interface. The browser window title is 'PeMS - Mozilla Firefox'. The URL is 'http://pems.eecs.berkeley.edu:3500/?dnode=search&content=cnt\_search&'. The page has a navigation bar with 'Home | Feedback | Account (pettyk) | Help | Logout' and a search box. Below the navigation bar, there are tabs for 'Real Time | Performance | Search | Explore'. A 'Jump to District...' dropdown is visible. The main content area is a map of Sacramento, California, with various overlays. On the left, there are several legend sections: 'ITS Stations' (Mainline, HOV, Ramps, Other), 'Count Locations' (Mainline, Ramps), 'Other' (LDSS, 511 ETC Readers (D4)), and 'Roadway' (Corridors, Managed Facilities). The 'Managed Facilities' section is expanded to show 'Link Status' with options for 'Open', 'Construction', and 'Proposed'. A popup window titled 'Open Managed Facility Link D3: I-80' is overlaid on the map, showing a table of occupancy requirements for different days and times. The table has columns for Sun, Mon, Tue, Wed, Thu, Fri, and Sat, and rows for 00:00, 06:00, 10:00, 15:00, 19:00, and 24:00. The occupancy requirements are shown as '2+' for HOV, Toll, HOT, Bus, Closed, and Open. The legend below the table indicates: HOV (red), Toll (green), HOT (yellow), Bus (blue), Closed (grey), and Open (white).

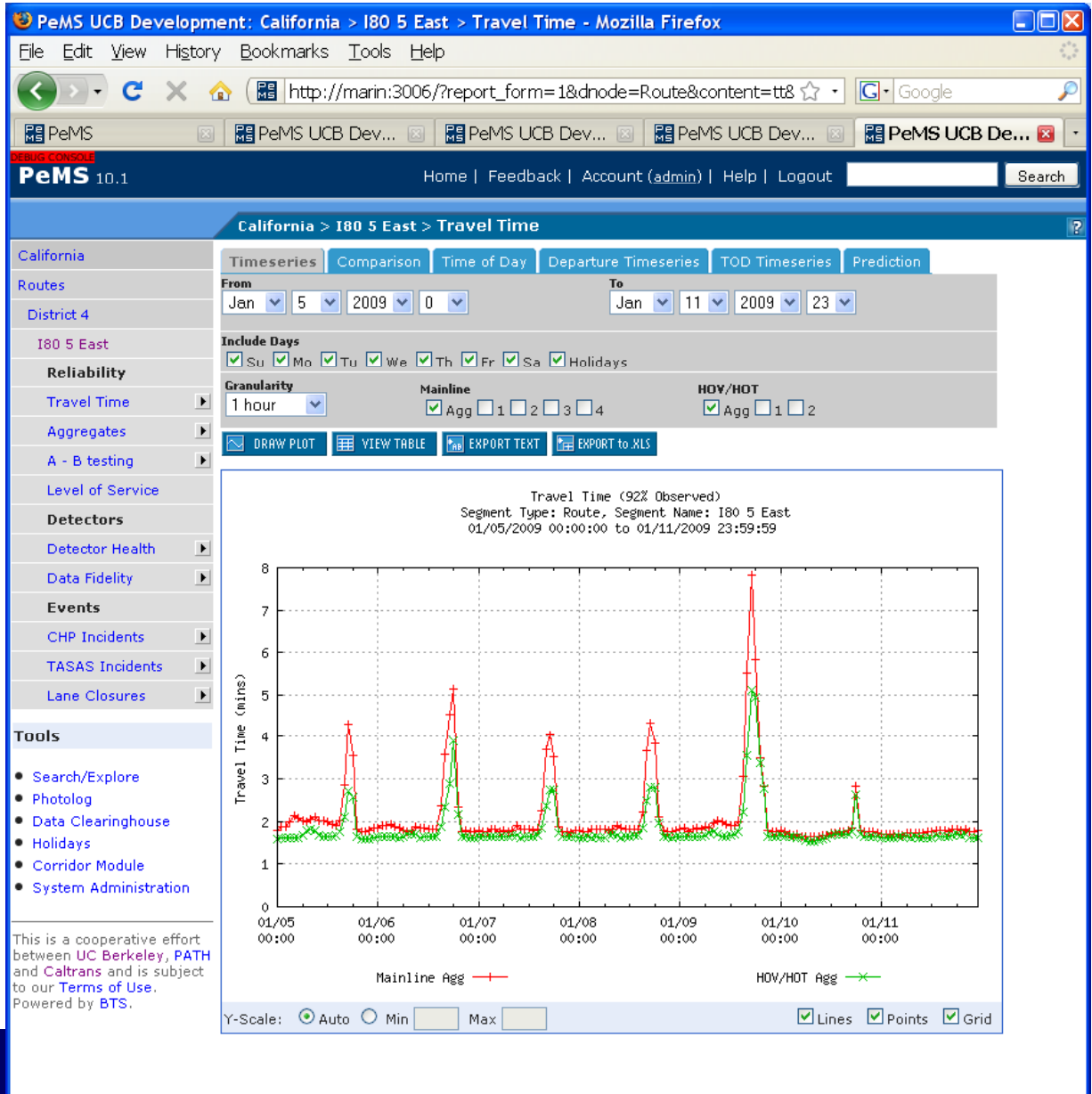
	Sun	Mon	Tue	Wed	Thu	Fri	Sat
00:00							
06:00		2+	2+	2+	2+	2+	
10:00							
15:00							
19:00		2+	2+	2+	2+	2+	
24:00							

Legend: HOV (red), Toll (green), HOT (yellow), Bus (blue), Closed (grey), Open (white)

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# Single Facility Reporting

- Standard solution for reporting: add all the reports and graphs that make sense
- We have two types of reports: travel time values and aggregate values (spatially summable values like delay)
- Here we're showing travel time for each mode: mainline and HOV

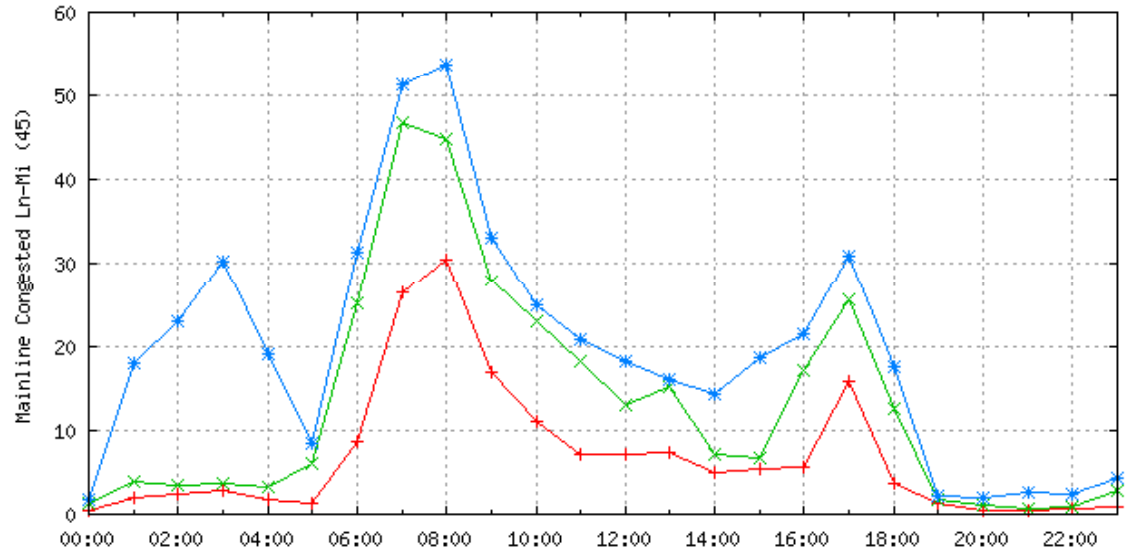




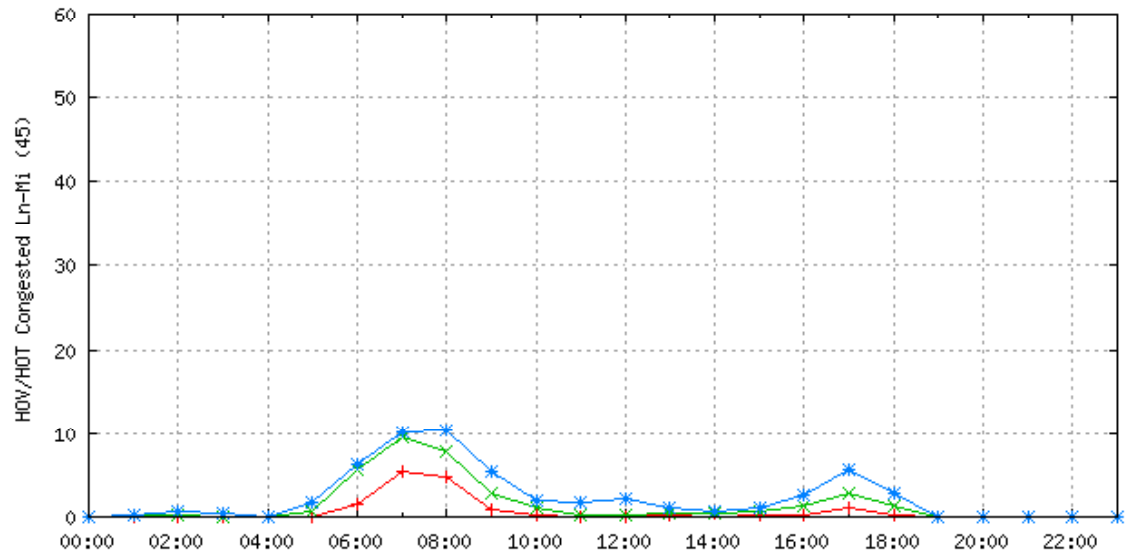
# Time of Day

- This is an example of an “aggregate” measure
- This is showing the “Congested Lane Miles” for a facility
  - Top plot = ML
  - Bottom plot = HOV
- Threshold is 45 mph (anything below 45 mph is considered congested)
- Versus time of day
- Over a month, weekdays
- Can see that the HOV congestion is quite a bit less than the ML congestion

Mainline Congested Ln-Mi (45)  
 Segment Type: Route, Segment Name: 210W-FruitToLake  
 12/01/2008 00:00:00 to 12/30/2008 23:59:59 (Days=Mo,Tu,We,Th,Fr)



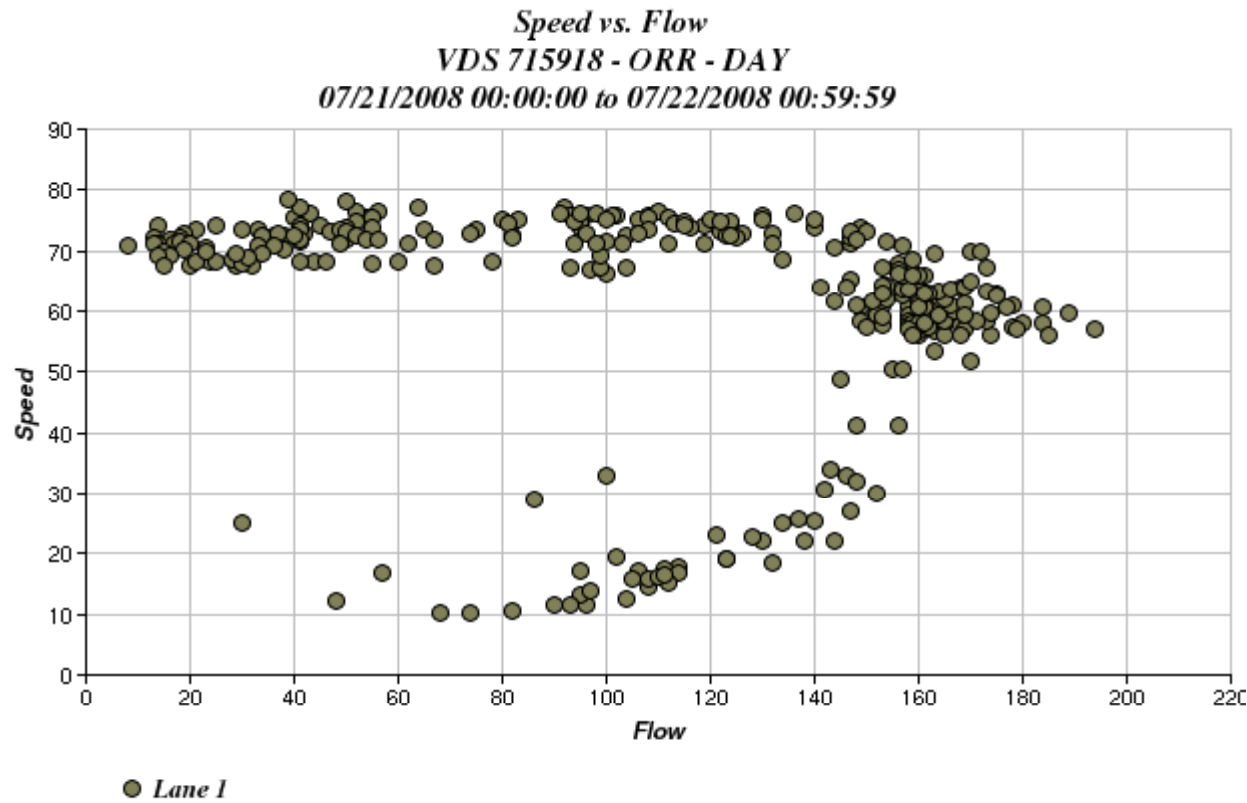
HOV/HOT Congested Ln-Mi (45)  
 Segment Type: Route, Segment Name: 210W-FruitToLake  
 12/01/2008 00:00:00 to 12/30/2008 23:59:59 (Days=Mo,Tu,We,Th,Fr)



25th —+— Median —x— 75th —\*—

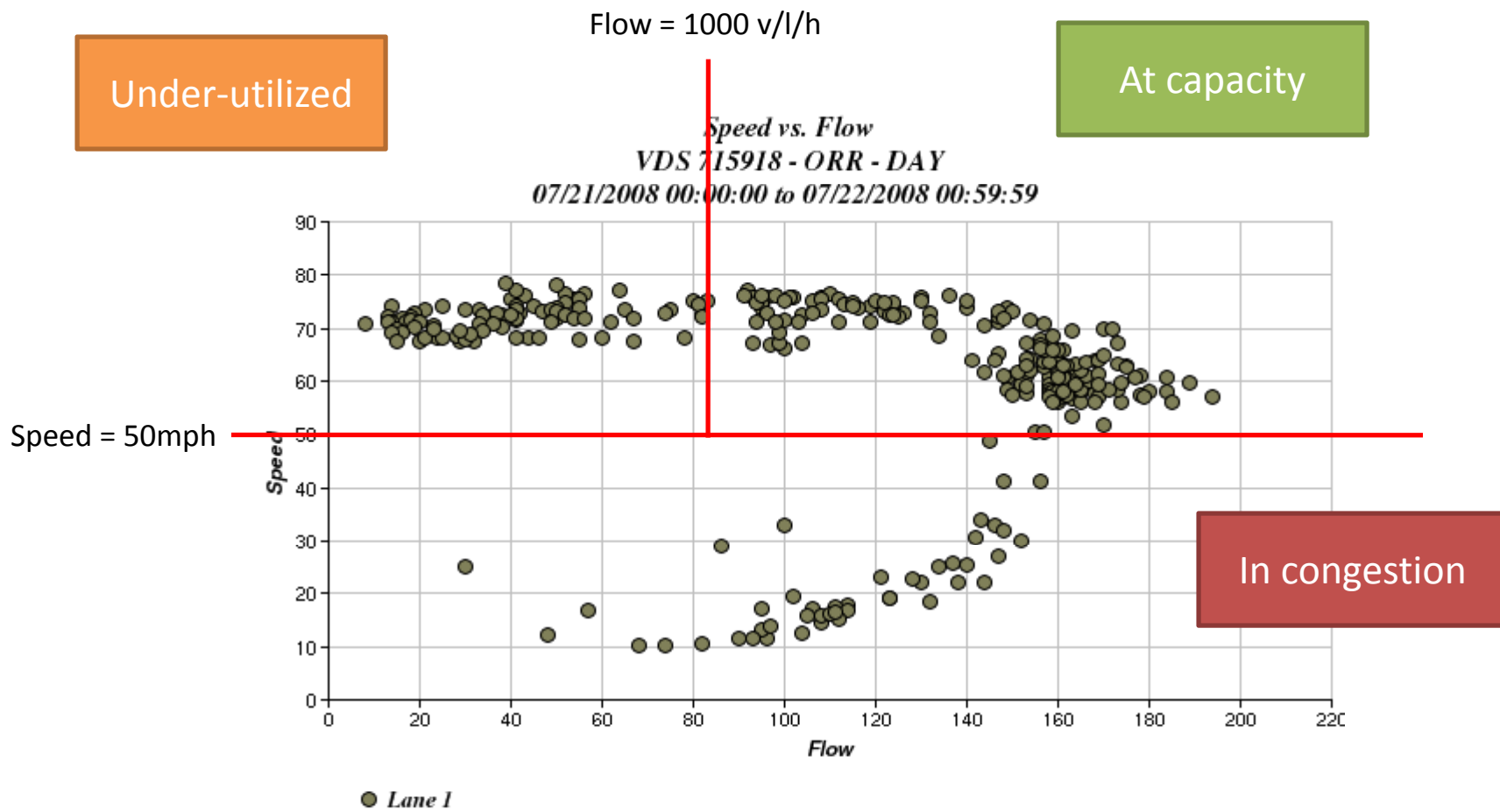
# New Measures and Visualizations

Fundamental diagram: shows speed versus flow (veh/5min) for an individual detector for one day



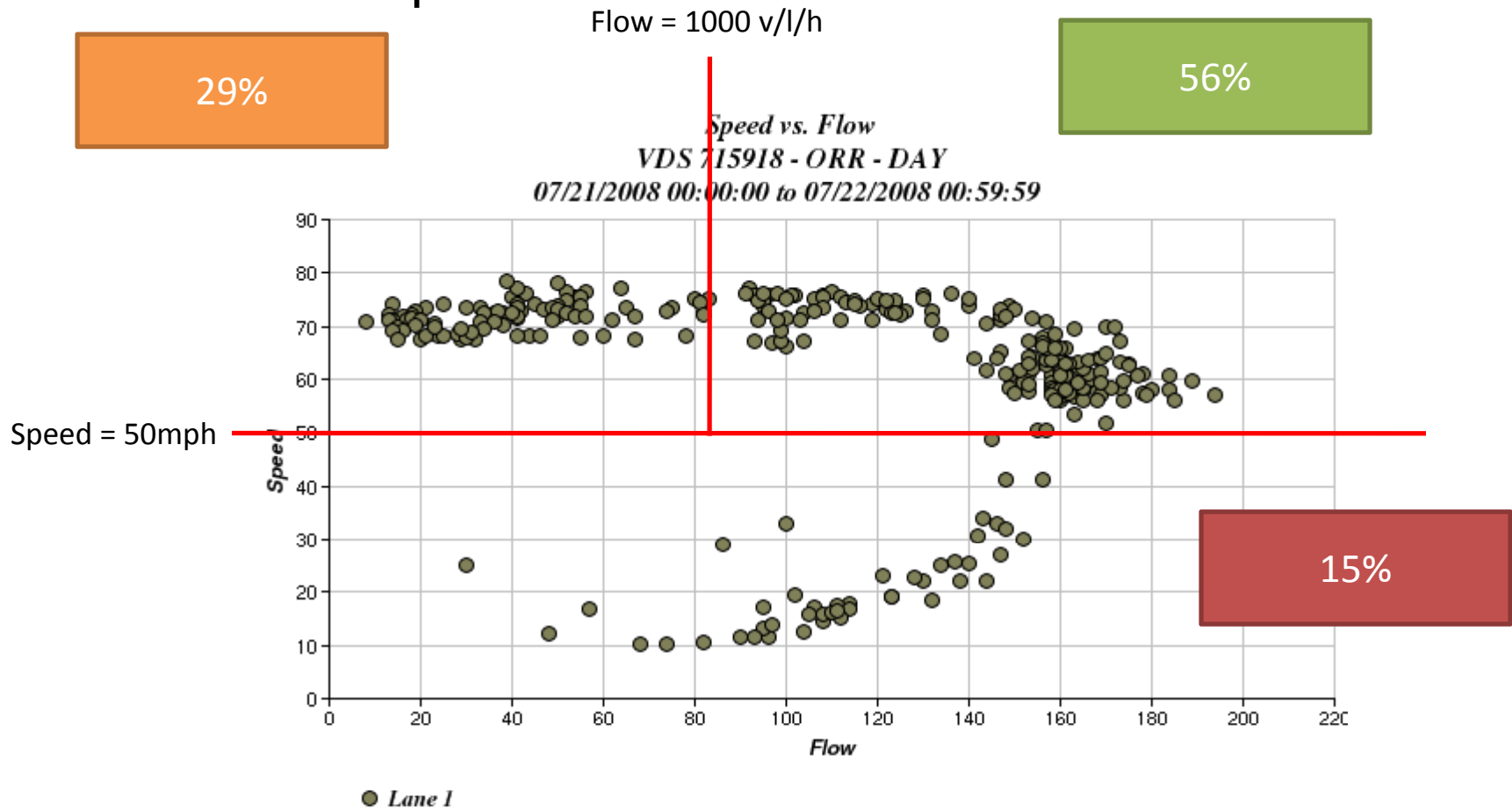
# Fundamental Traffic Diagram

We can divide different regimes into three groups



# Translation to a Performance Measure

How much time was spent in each regime? Simply count the number of points.

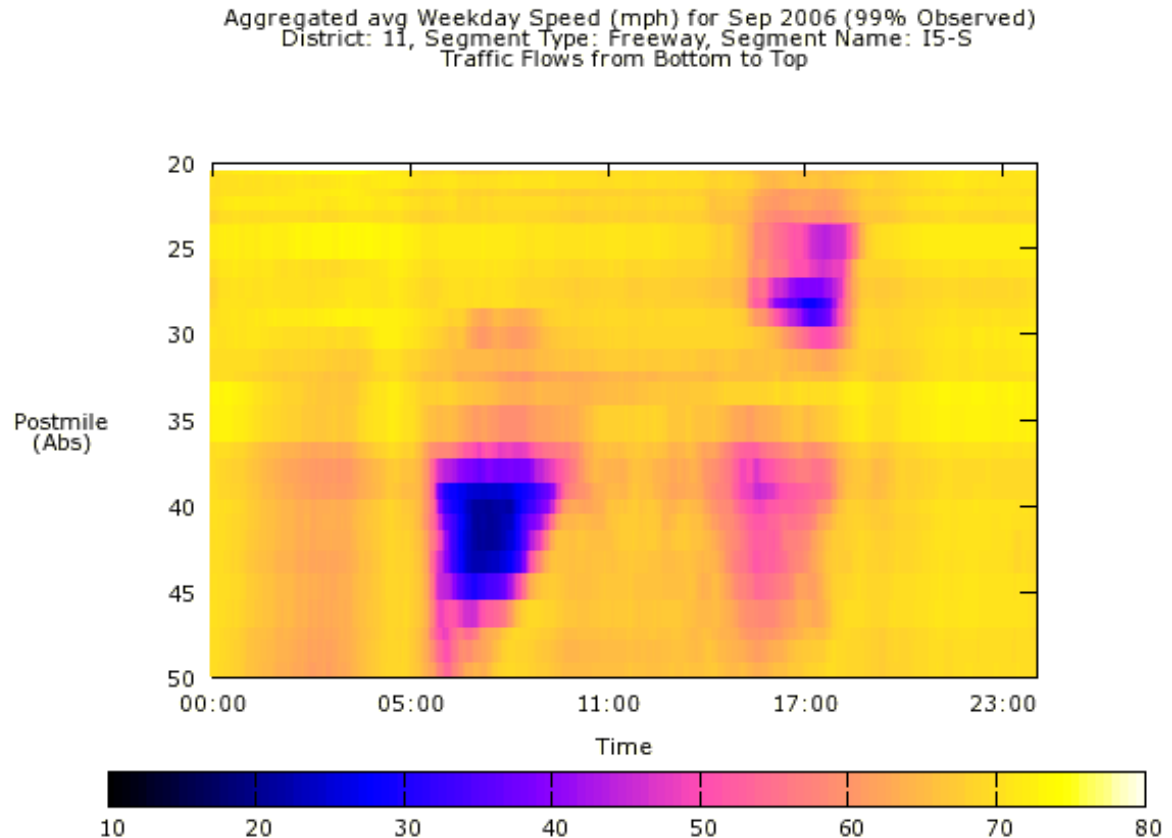


## Translation to a Facility Measure

- The previous measures were for a single location. But down a freeway we'll have different **regions** in congestion for different amounts of **time** during the day.
- For the spatial factor (regions) need to weight the percentage of time in each regime by:
  - Number of lanes
  - Length of freeway segment assigned to each detector
  - This will give us lane-miles
- For the time dimension, we need to perform this for an hour at a time
- The final units are “lane-mile-hours”

# Translation to a Facility Measure

- Another way to think about it: speed contour diagrams
- Simply looking for the regions when the facility is in congestion
- On this diagram you can clearly see the congestion



“How much of the time is spent in congestion? When it’s not in congestion, how much of the time is spent being fully utilized?”

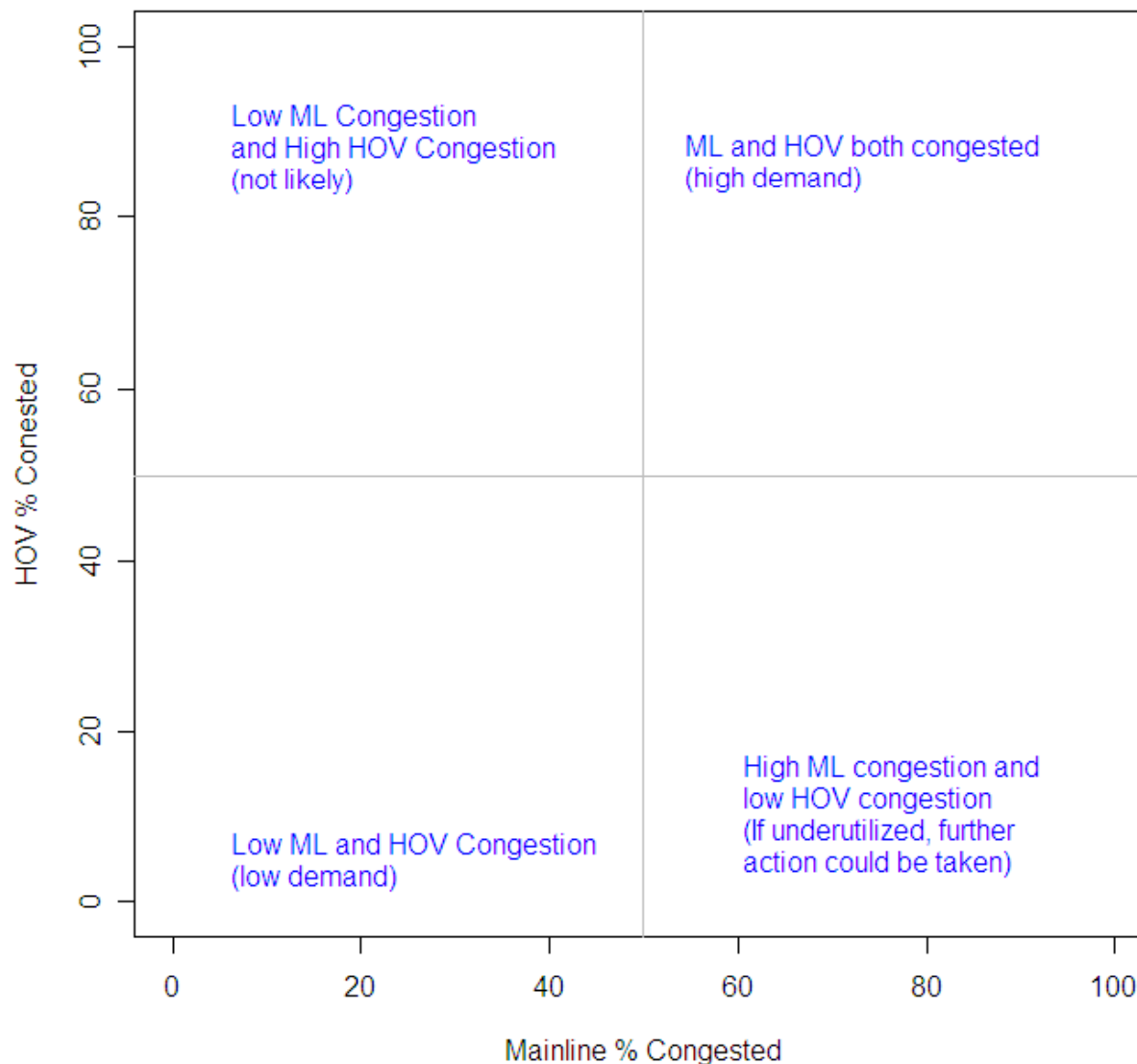
## Translation to an HOV/Mainline Facility Measure

- For a single facility, either HOV or Mainline, we can compute the following types of statistics:
  1. % of lane-mile-hours spent in congestion (speed < 50 mph)
  2. % of lane-mile-hours spent under-utilized (speed > 50 mph; flow < 1000 v/l/h)
  3. % of lane-mile-hours spent at capacity (speed > 50 mph; flow > 1000 v/l/h)
- We can plot the Mainline and HOV quantities against each other
- Caveat:
  - HOV capacities are typically less than ML capacities
  - For the HOV threshold of “under-utilized” we used 750 v/l/h
  - This can be changed, of course

# Facilities

- We'd like to get a sense of how the HOV + ML facility is doing as a whole
- Plot HOV quantity versus ML quantity
- Each facility-shift will be a dot on this map
- Use % lane-mile-hours congested

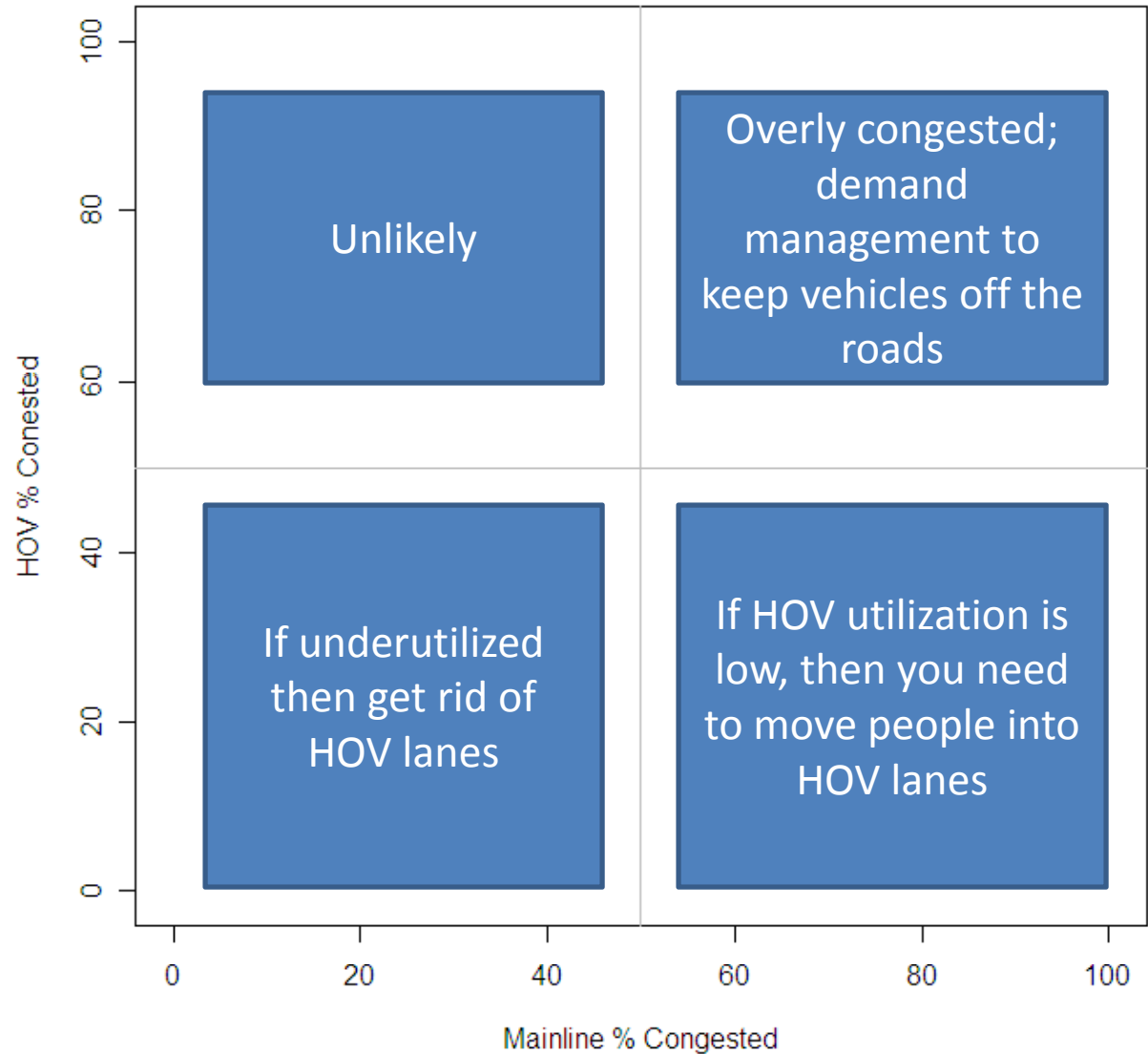
HOV Facility-Level Performance



# Actions

- Each region suggests a management action
- The facilities can be further studied (through other plots in PeMS) to determine the correct action

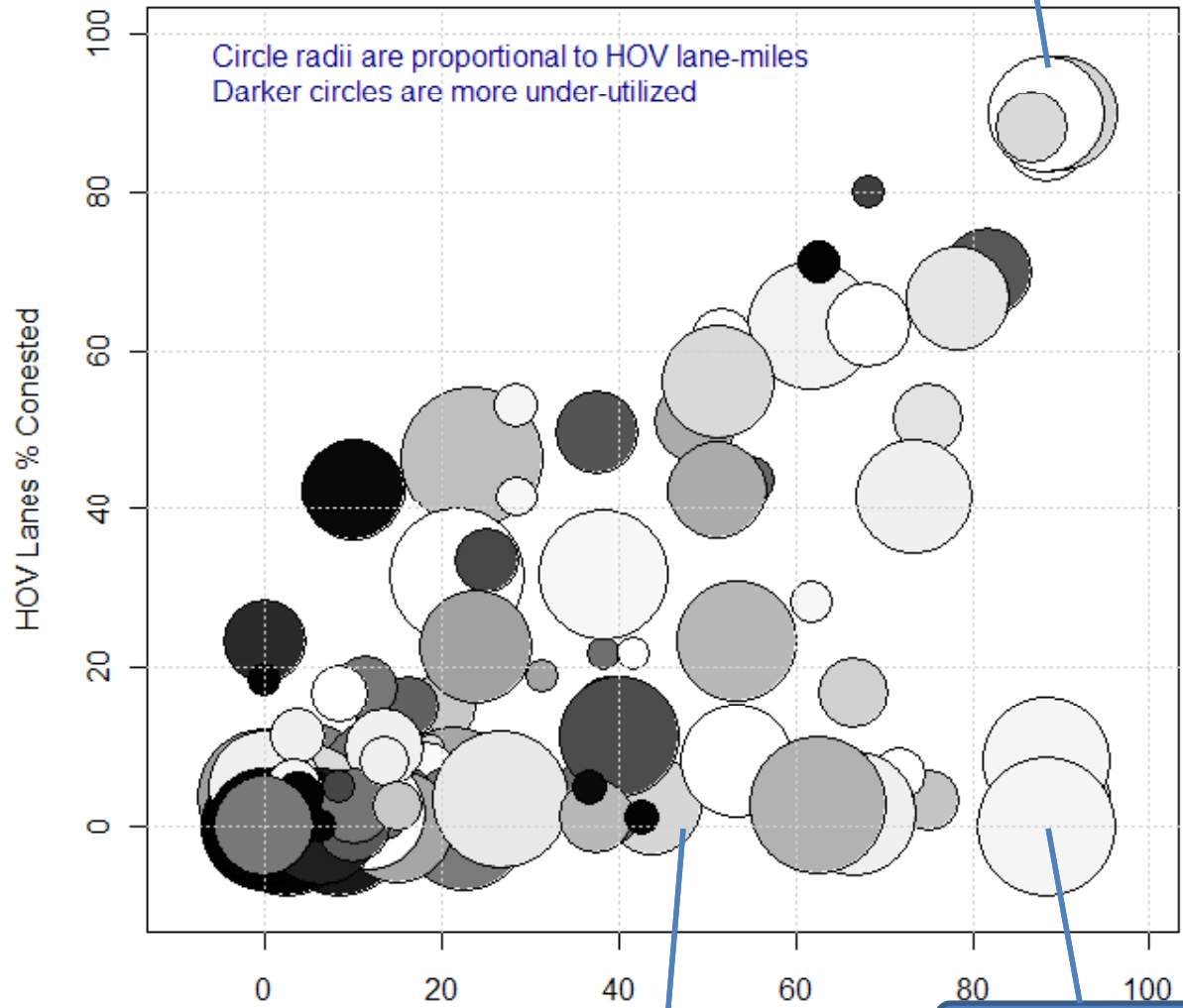
HOV Facility-Level Performance



# Facilities

- Each dot is a facility-direction-shift
- This size of the dot is related to the HOV lane-miles
- The darker circles are more under-utilized
- This is for the month of May 2009, weekdays, peak periods only
- You want light circles in the lower right corner
- A dark circle in the lower left-hand corner implies you don't need an HOV lane at all

HOV Facility-Level Performance



D7 405S PM

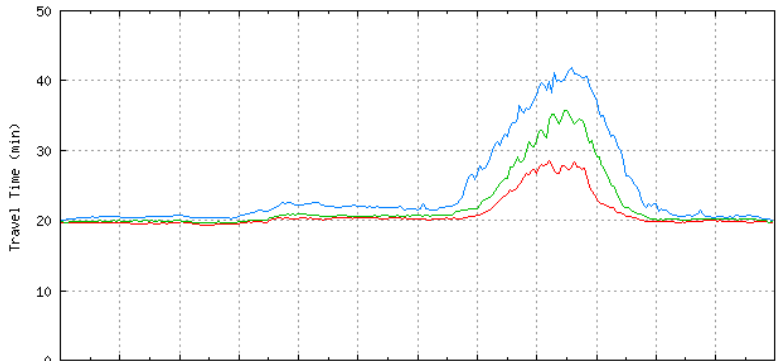
D12 91W AM

D7 110S PM

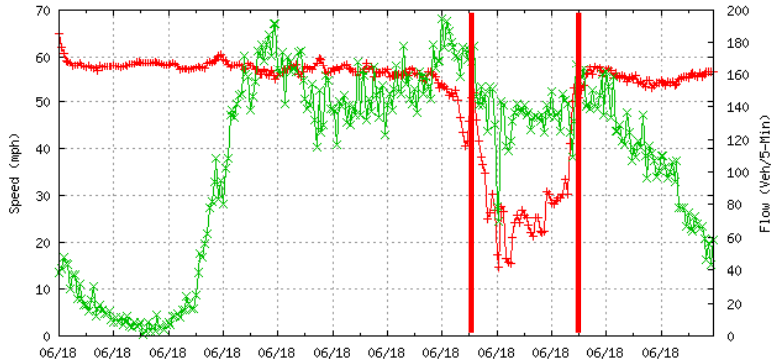
Travel Time Variability (44% Observed)  
 Segment Type: Route, Segment Name: 405 Santa Monica Blvd (near) to 710 South  
 06/01/2008 00:00:00 to 06/30/2008 23:59:59 (Days=Mo,Tu,We,Th,Fr)

**D7 405S PM**

**Weekday  
 travel time vs  
 time of day**

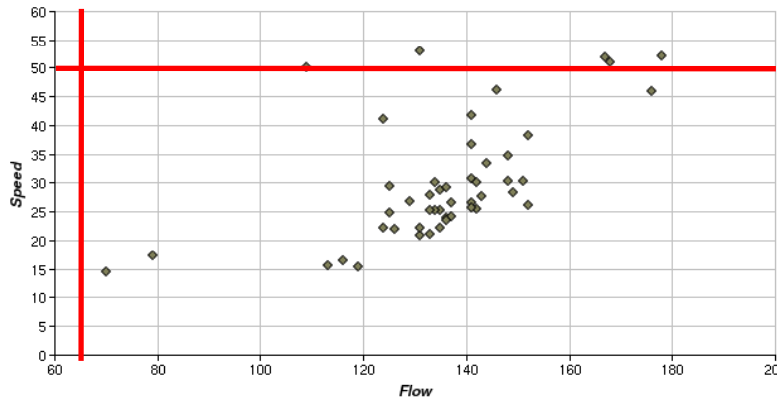


**HOV – 761523 (1 lane)**



**Flow, Speed  
 vs Time**

*Speed vs. Flow*  
**VDS 761523 - NORMANDIE 1**  
 06/18/2008 15:00:00 to 06/18/2008 18:59:59

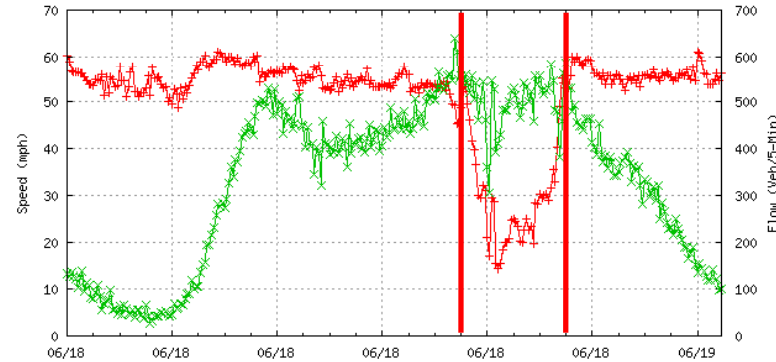
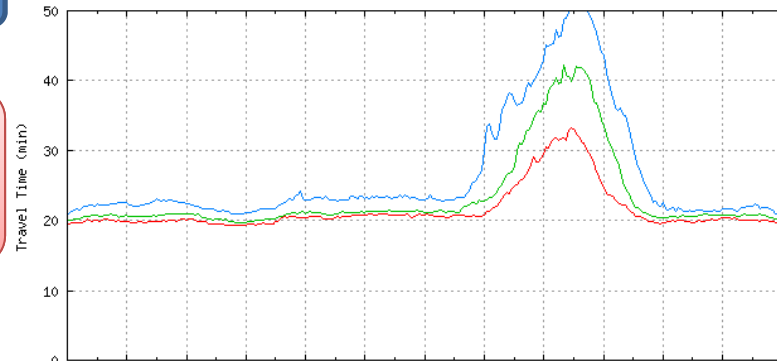


**Speed vs  
 Flow**

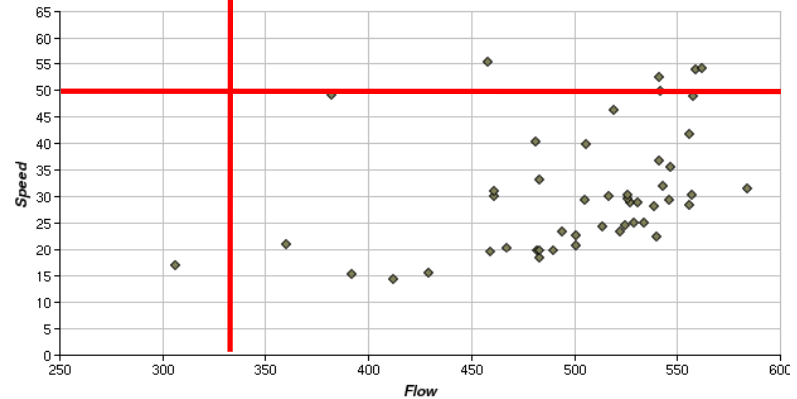
◆ Aggregate

Travel Time Variability (44% Observed)  
 Segment Type: Route, Segment Name: 405 Santa Monica Blvd (near) to 710 South  
 06/01/2008 00:00:00 to 06/30/2008 23:59:59 (Days=Mo,Tu,We,Th,Fr)

**Mainline – 761526 (4 lanes)**



*Speed vs. Flow*  
**VDS 761526 - NORMANDIE 1**  
 06/18/2008 15:00:00 to 06/18/2008 18:59:59



◆ Aggregate

## Summary

- Caltrans is transitioning to automated HOV facility performance monitoring
- Drivers: compliance with federal standards, political pressure
- Implementing many different types of measures
  - Improving usability
- Working on measures and visualizations that directly link to actions

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**Questions?**