Analyzing Bay Bridge Westbound Traffic

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Research Team

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Research Motivation

- San Francisco—Oakland Bay Bridge (SFOBB) is arguably the most important bridge in the Bay Area, but traffic congestion is severe
- Replacement of the Eastern Span cost $6.5 Billion, so adding additional capacity is highly unlikely
- With tolling and more complicated roadway geometry in the Westbound direction, it is important to study Westbound traffic

Defining the Problem

- Understand the severity and causes of Westbound AM-peak congestion
- Determine general relationship between metering rate and traffic conditions
- Suggest solutions to improve the operation of the bridge
- Compare traffic conditions in 2016 to those found in 2015 study

Outline

- Bridge Statistics
- Understanding Bridge Geometry
- Research Methodology & Data Sources
- 2015 Study

- Tollbooth Area
  - M/D/1 Queue
- Metering Area
- Merging Area
- Congestion Patterns

Bridge Statistics

- San Francisco—Oakland Bay Bridge (SFOBB) serves an average of 132,000 vehicles westbound each day
- Demand will only increase, as Bay Area population is expected to increase by 30% between 2010 and 2040[1]
- 2nd most congested segment in Bay Area and 16th most in nation[2]

Top 50 Congested Locations, 2015 — Ordered by Rank

Rank	COUNTY	ROUTE	DIR.	DAILY DELAY (vehicle hours)	CONGESTION DURATION	LOCATION
1	SF	US-101/I-80	NB/EB	13,710	12:50 PM–9:30 PM	I-280 to Treasure Island Tunnel
2	CC/ALA/SF	I-80	WB	13,010	5:35 AM–7:50 PM	CA-4 to US-101

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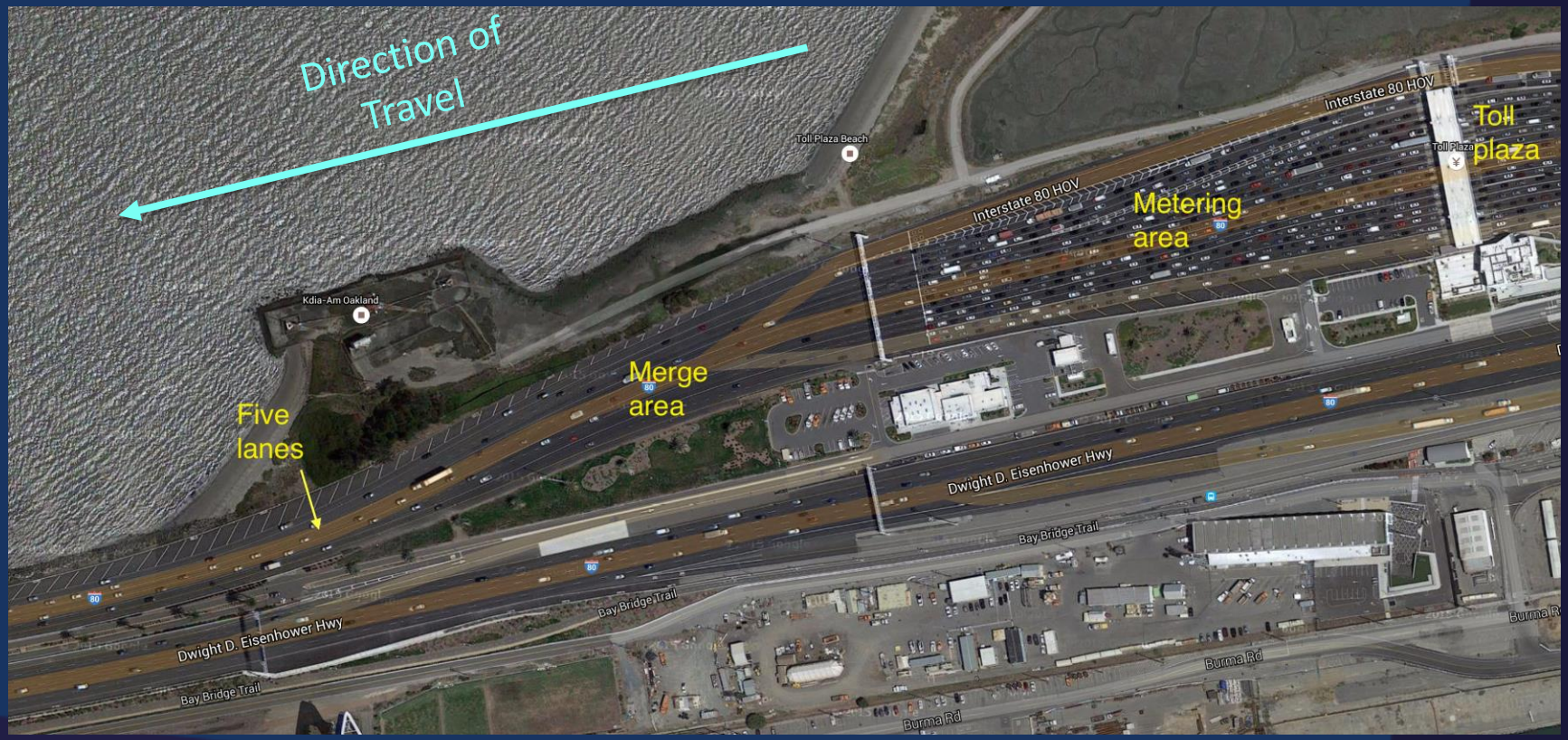
1. According to Metropolitan Transportation Commission (MTC)
2. According to MTC and American Highway Users Alliance, respectively

Geometry of Westbound Entrance



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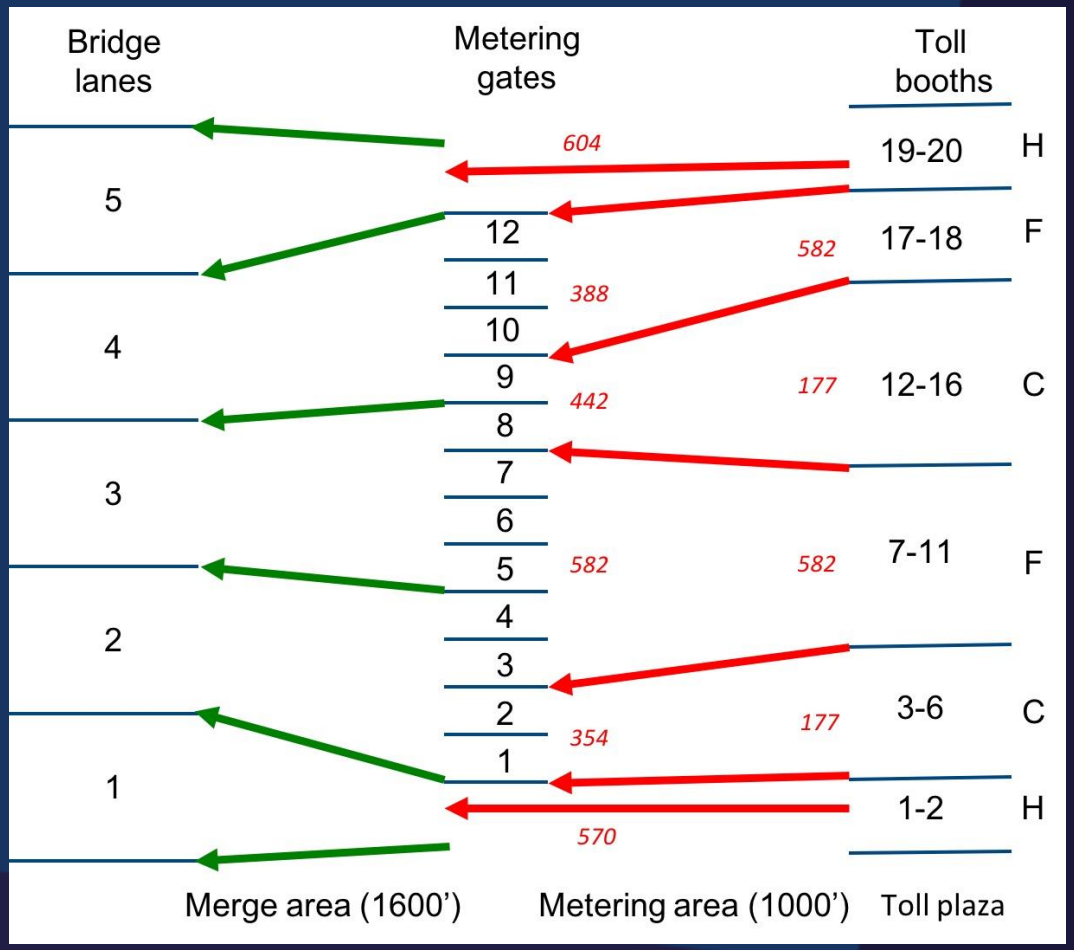
Geometry of Westbound Entrance

- 16 tollbooths (3-18)
- 4 HOV lanes (1-2 & 19-20)
- Red numbers denote volume in vehicles per hour per lane



Research Methodology & Data Sources

- Analyze 3 phases of bridge
  - Tollbooth Area
  - Metering Area
  - Merging Area

- Compare congestion patterns to those found in 2015

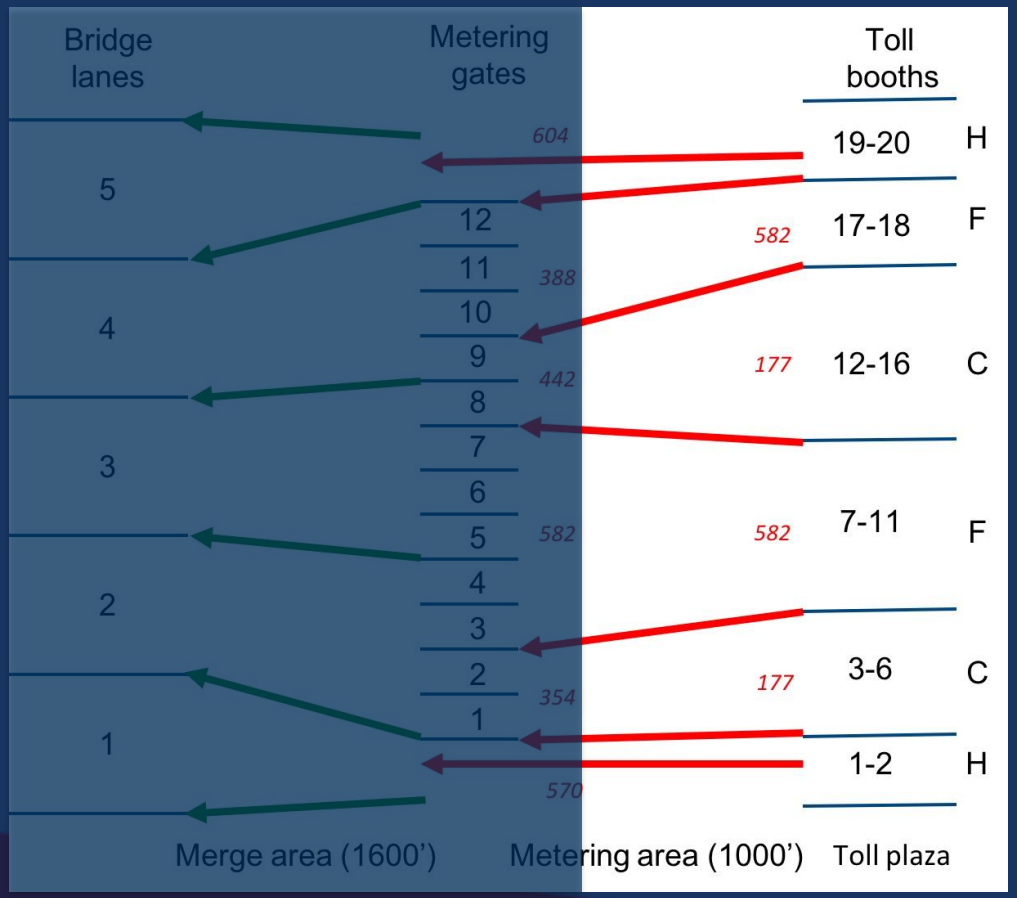
- Data Sources
  - PeMS
  - Independent Tollbooth Counts
  - Metering Logs
  - Video Recordings

SFOBB 2015 Study

Z. Amini, A. Skabardonis, P. Varaiya, "An investigation of the operation of the metering system at the San Francisco-Oakland Bar Bridge", TRB 95th annual meeting, Washington, D.C., January 10-14, 2016.

- Before metering is activated, there is early congestion at the merging area due to high volumes in the middle lanes
- Little correlation between the metering rate and number of vehicles that pass the tollbooths
- Around 8-9 AM, congestion begins West of Yerba Buena Island and propagates upstream all the way to the merging area
- HOV lanes generally have lower flows and are underutilized after 9 AM

Tollbooth Area



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Tollbooth Area: Overview

- Fastrak vehicles can access 8 metering gates, whereas cash vehicles can only access 4
- On average, 582 vph for Fastrak lanes and 177 vph for Cash/Fastrak lanes
- HOV lanes pay a smaller toll and are FasTrak only

Tollbooth Area: M/D/1 Queue

- λ = demand per hour
- μ = service rate per hour
- Q = average length of queue
- W = average waiting time

$$\rho = \frac{\lambda}{\mu}$$

$$Q = \frac{1}{2}\left(\frac{\rho^2}{1-p}\right)$$

$$W = \frac{\rho}{2\rho(1-\rho)}$$

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Tollbooth Area: M/D/1 Queue

	Q	ρ	λ	μ	W
Fastrak	20, 40	0.975, 0.99	582	597, 588	124, 248
Cash	20,40	0.975, 0.99	177	181, 179	406, 812

$$\rho = \frac{\lambda}{\mu}$$

$$Q = \frac{1}{2}\left(\frac{\rho^2}{1-p}\right)$$

$$W = \frac{\rho}{2\rho(1-\rho)}$$

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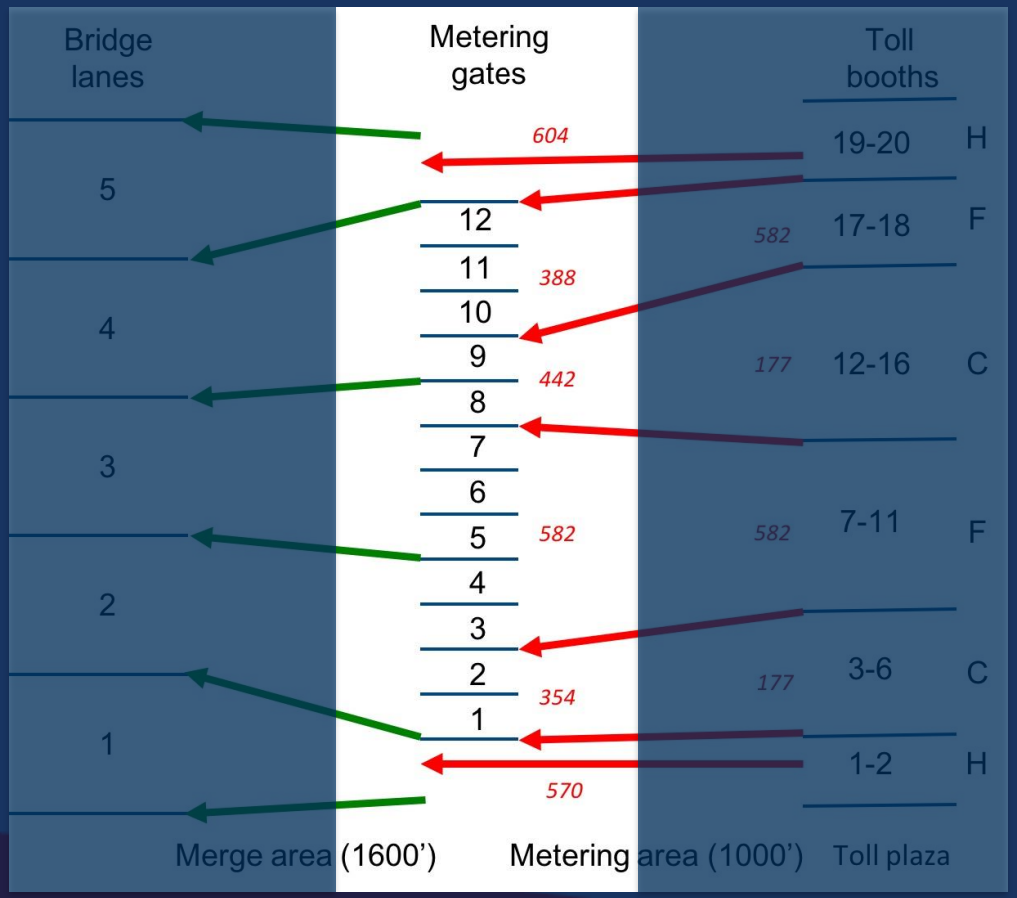
Metering Area



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Metering Area Overview

- At the time of study, operator manually adjusted metering rates based on congestion they saw at the metering area
- Metering logs indicate the metering rate in vehicle per minute and the time that it changes at
- In addition, metering logs provide the table that the operator selected, which indicates the ratio of Fastrak to Cash lane greens

TIME	TYPE OF METERING	METERING RATE		REASON FOR RATE CHANGE	TABLE
5:31	fixed	60		Congested @ Merge	21
5:34		180			21
6:00		160		Congested @ merge	21

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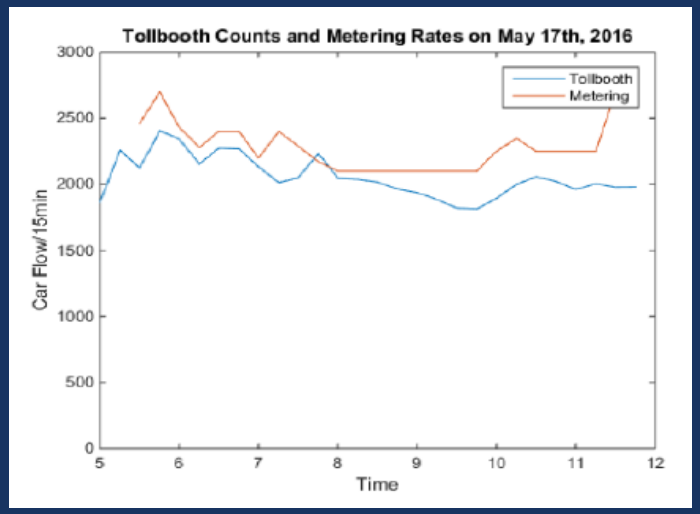
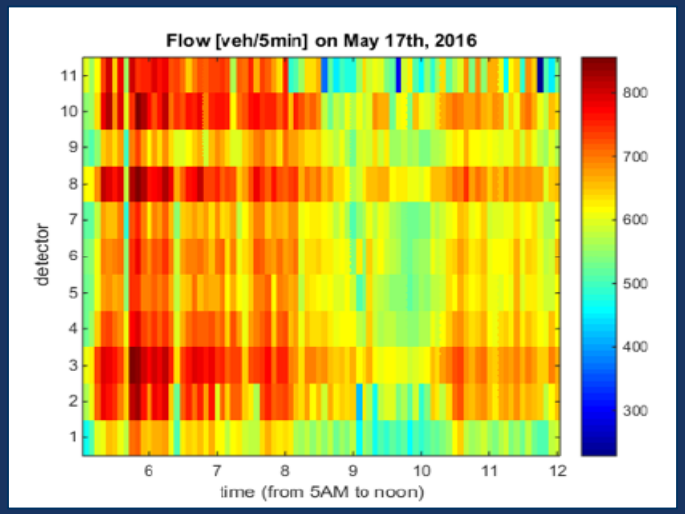
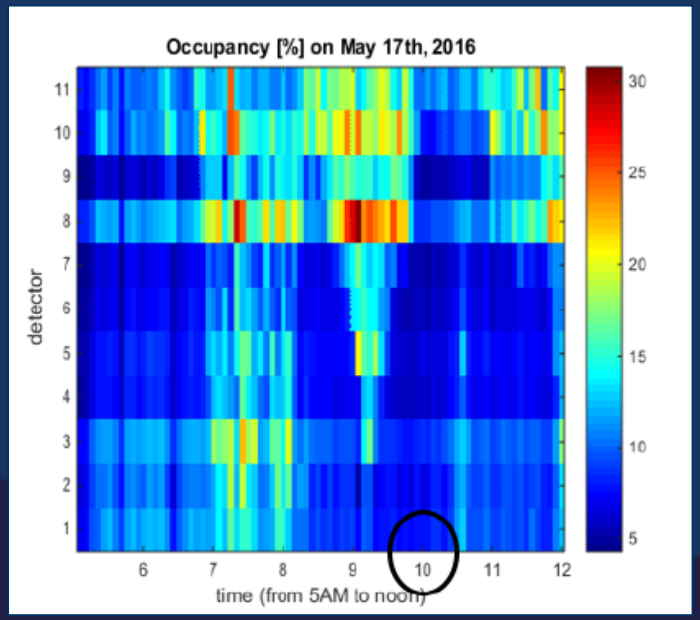
Metering Rates and Tollbooth Counts

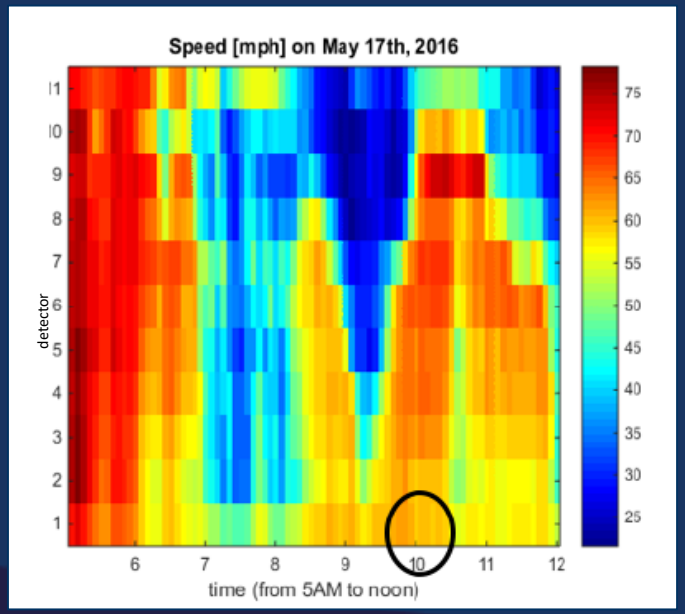
- Tollbooth counts (proxy for demand) and metering rates roughly mirror each other, which makes sense given operating regime
- PeMs data provides more evidence that metering rates are dictated by traffic conditions

May 17, 2016









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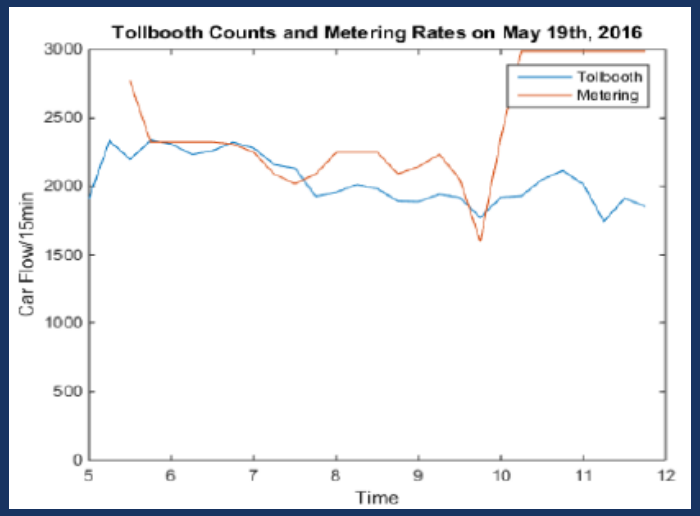
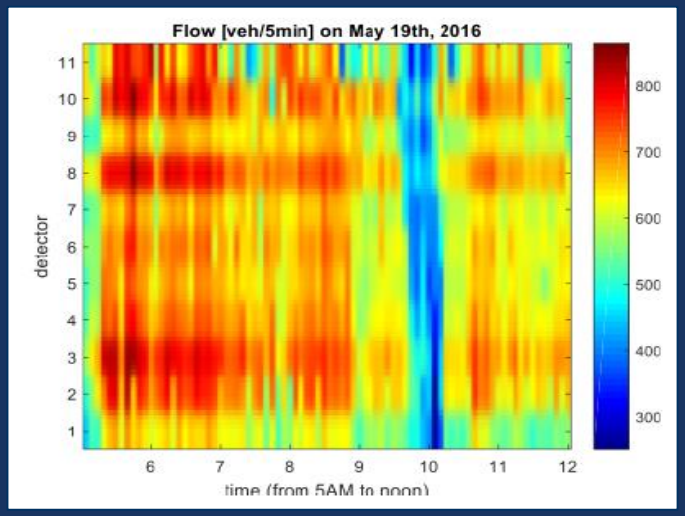
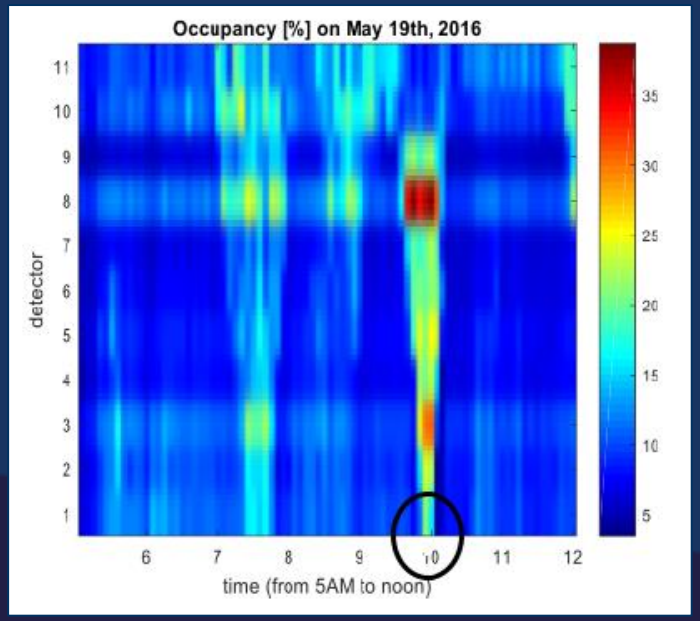
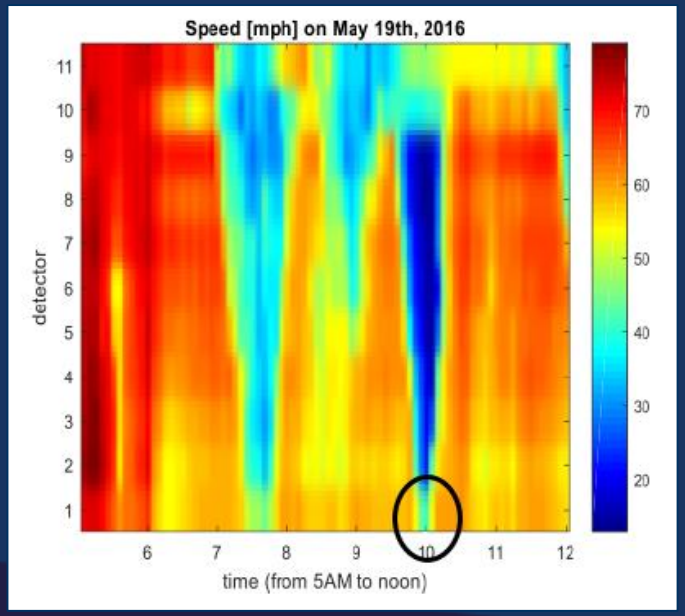
May 19, 2016









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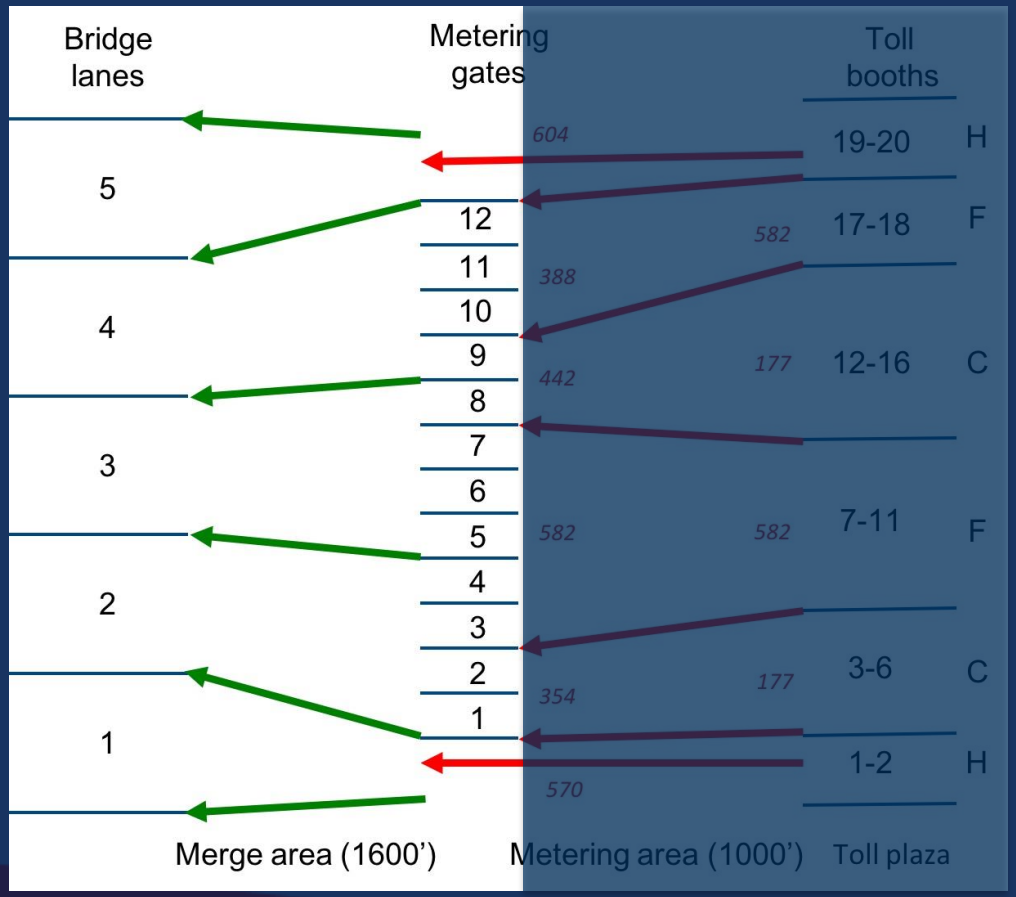
Merging Area



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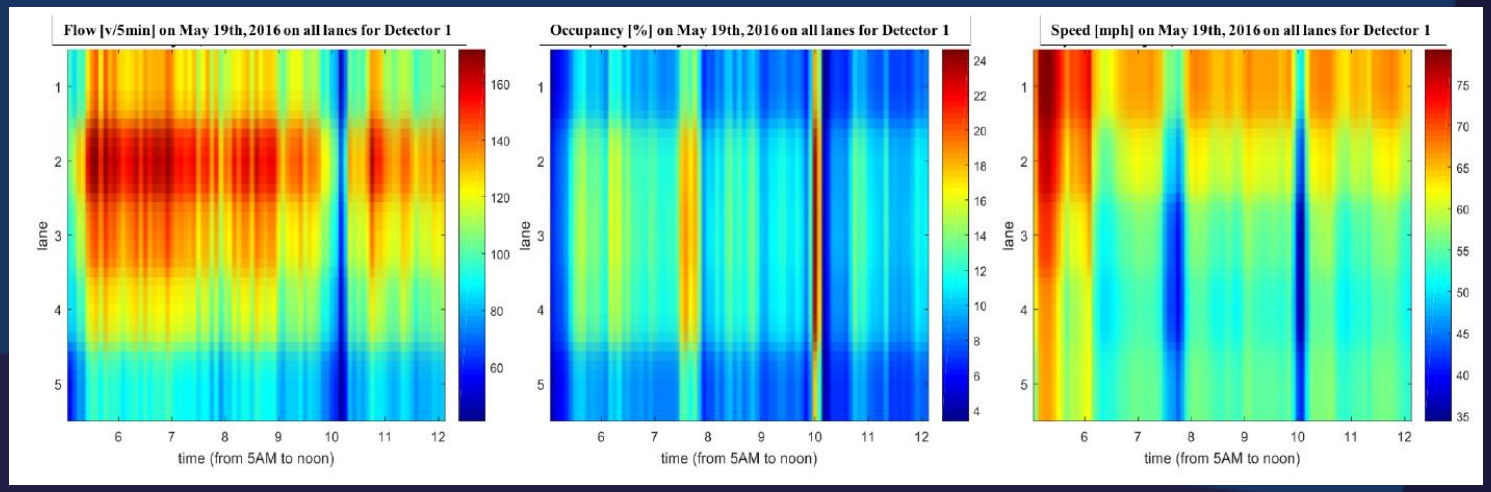
Merging Area Flow

- HOV lanes feed into lanes 1 and 5, whereas Fastrak/Cash lanes feed into lanes 2-4
- HOV lanes are under-utilized during 5-6AM and 9-10AM
- PeMS data confirms trends implied by the Tollbooth Counts

Merging Area Flow

	4-5AM	5-6AM	6-7AM	7-8AM	8-9AM	9-10AM
Lane 1	50	1403	1874	1888	1345	742
Lane 5	0	895	1381	1701	1611	816
Lanes 2-4 (avg)	1595	2400	2016	1640	1910	1909



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Congestion Patterns

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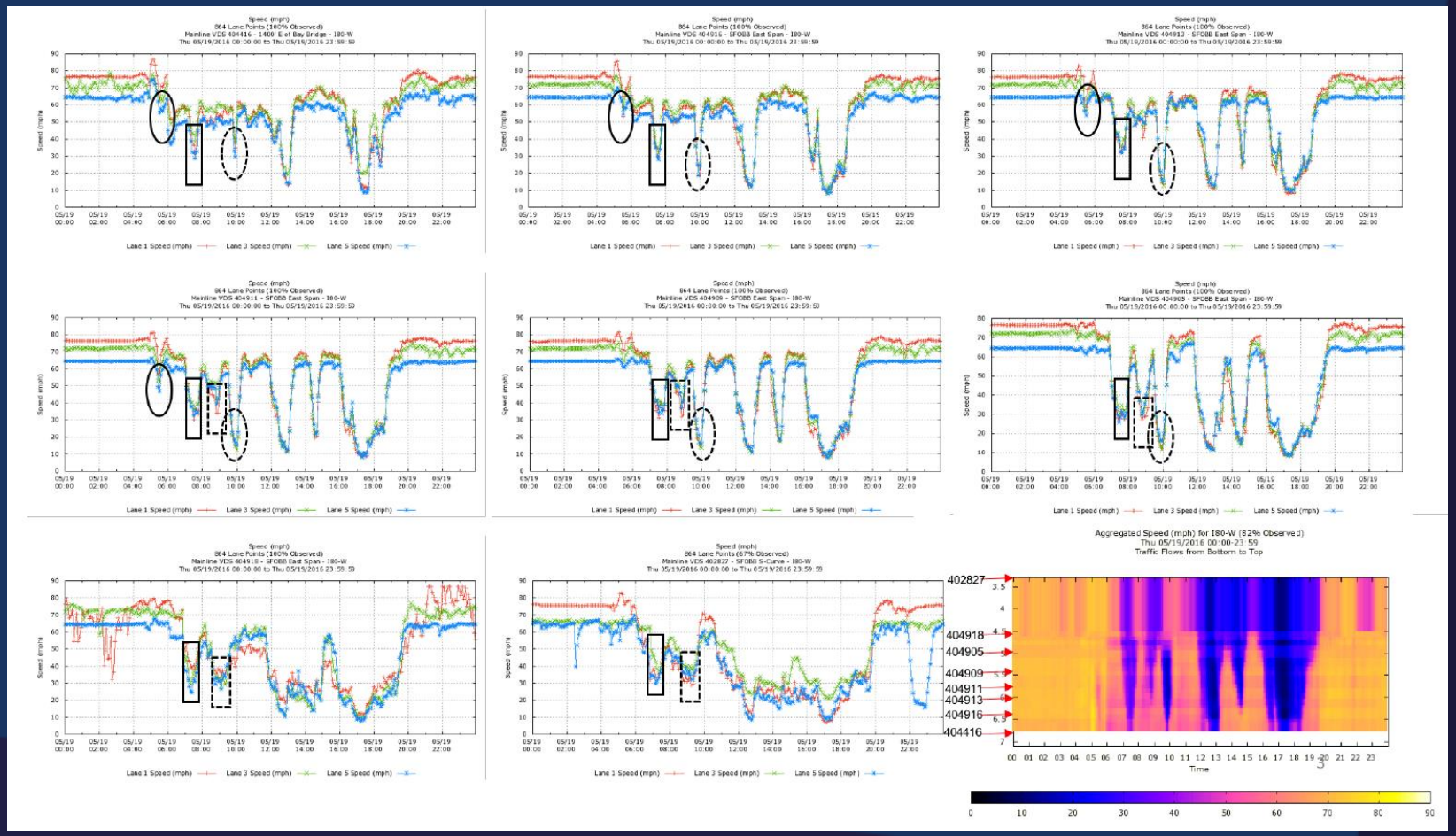
Congestion Patterns in 2016



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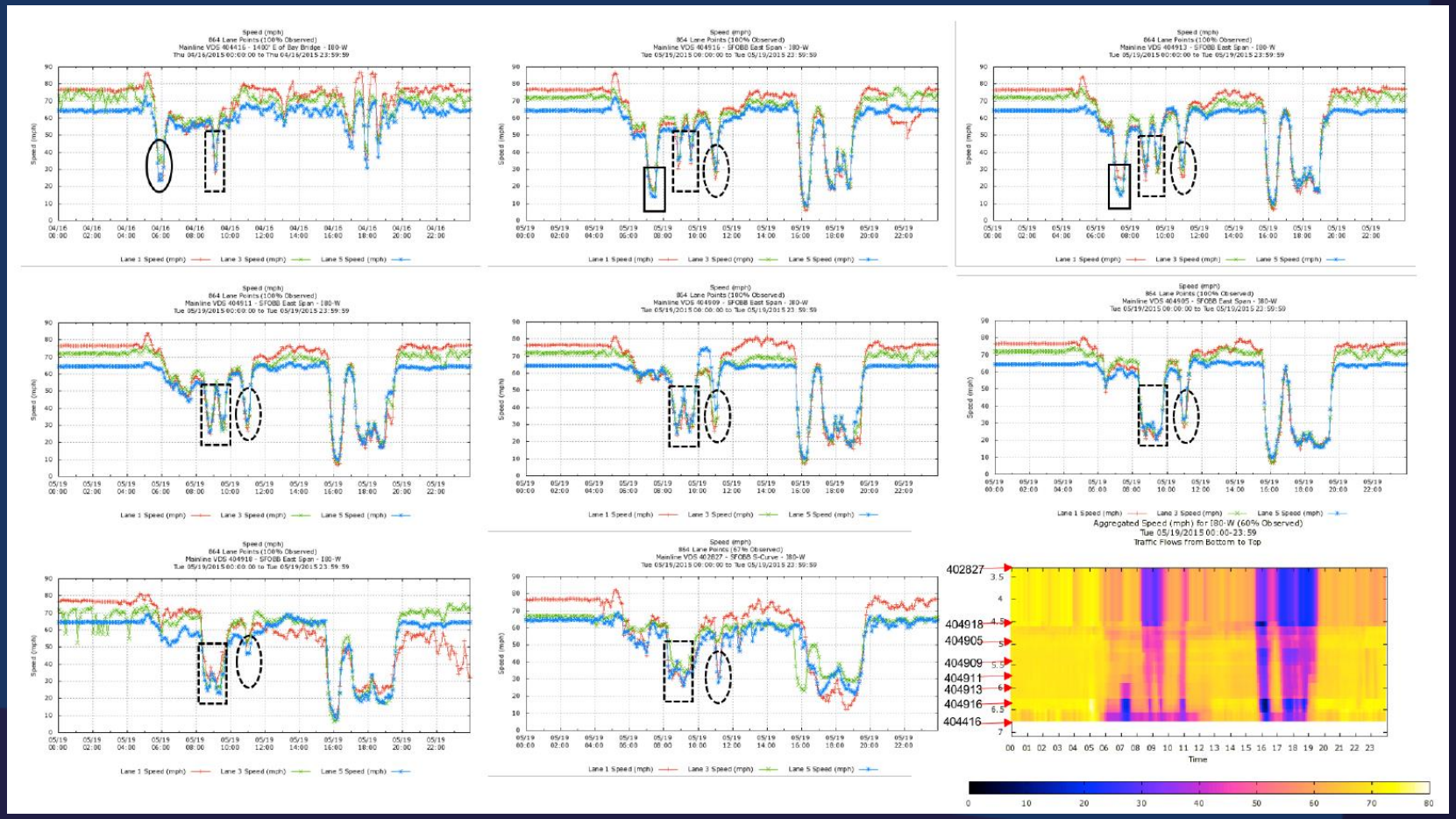
Congestion Patterns in 2015



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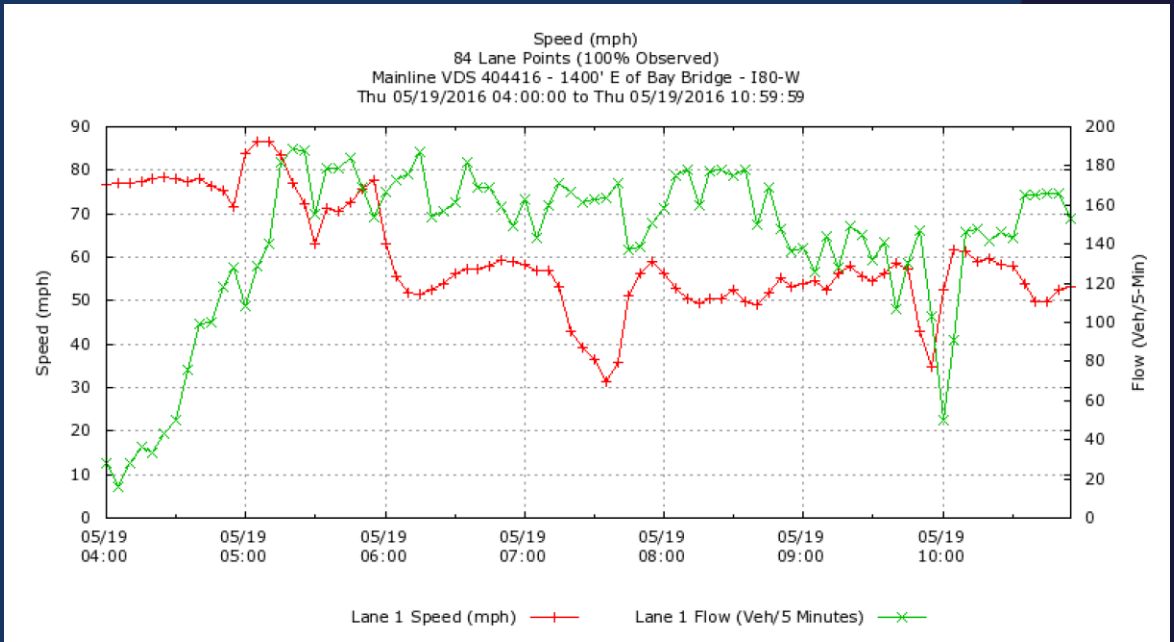
2016: 10am Congestion

- Congestion increases at 10am
- At 10am, toll price is reduced and HOV lane restriction is lifted



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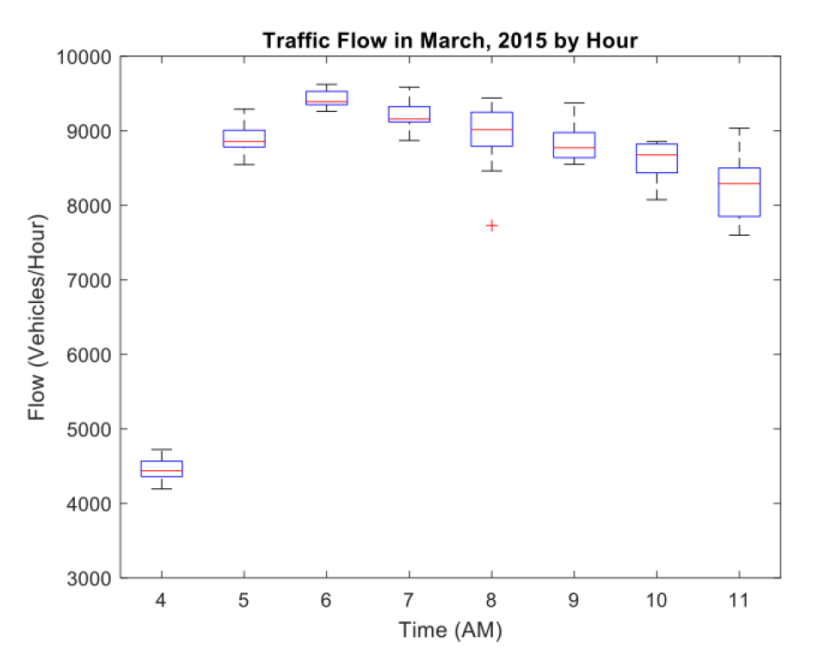
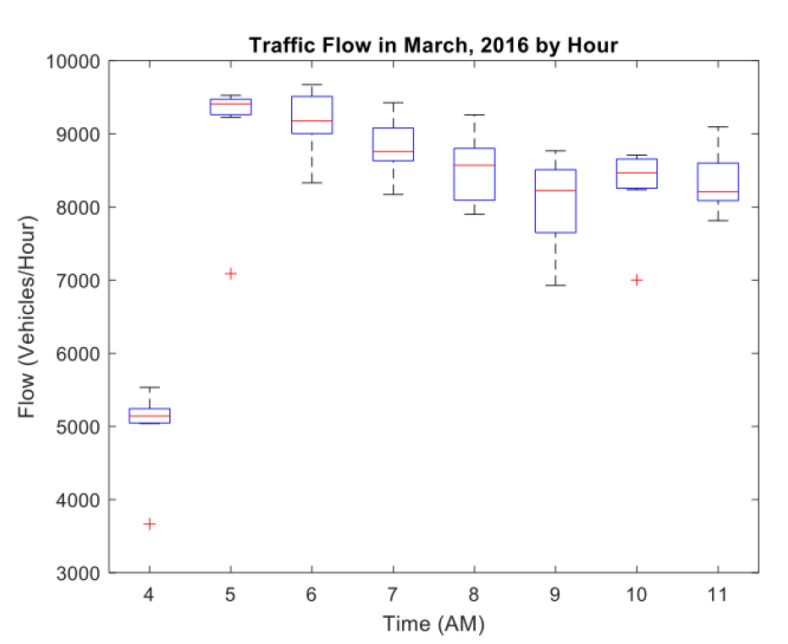
2015 vs 2016 Congestion





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Conclusions

- HOV lanes are under-utilized from 5-6 AM and 9-10 AM
- Travelers in 2016 arrived at the bridge earlier than in 2015
- Congestion waves propagate upstream from West of Yerba Buena Island
- At the time, no detectors on West Span of bridge, making it difficult to determine the causes of these congestion patterns