UDOT AUTOMATED TRAFFIC SIGNAL PERFORMANCE MEASURES

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Opportunity from UDOT Executive Leaders (2011)

"What would it take for UDOT's traffic signals to be world class?"

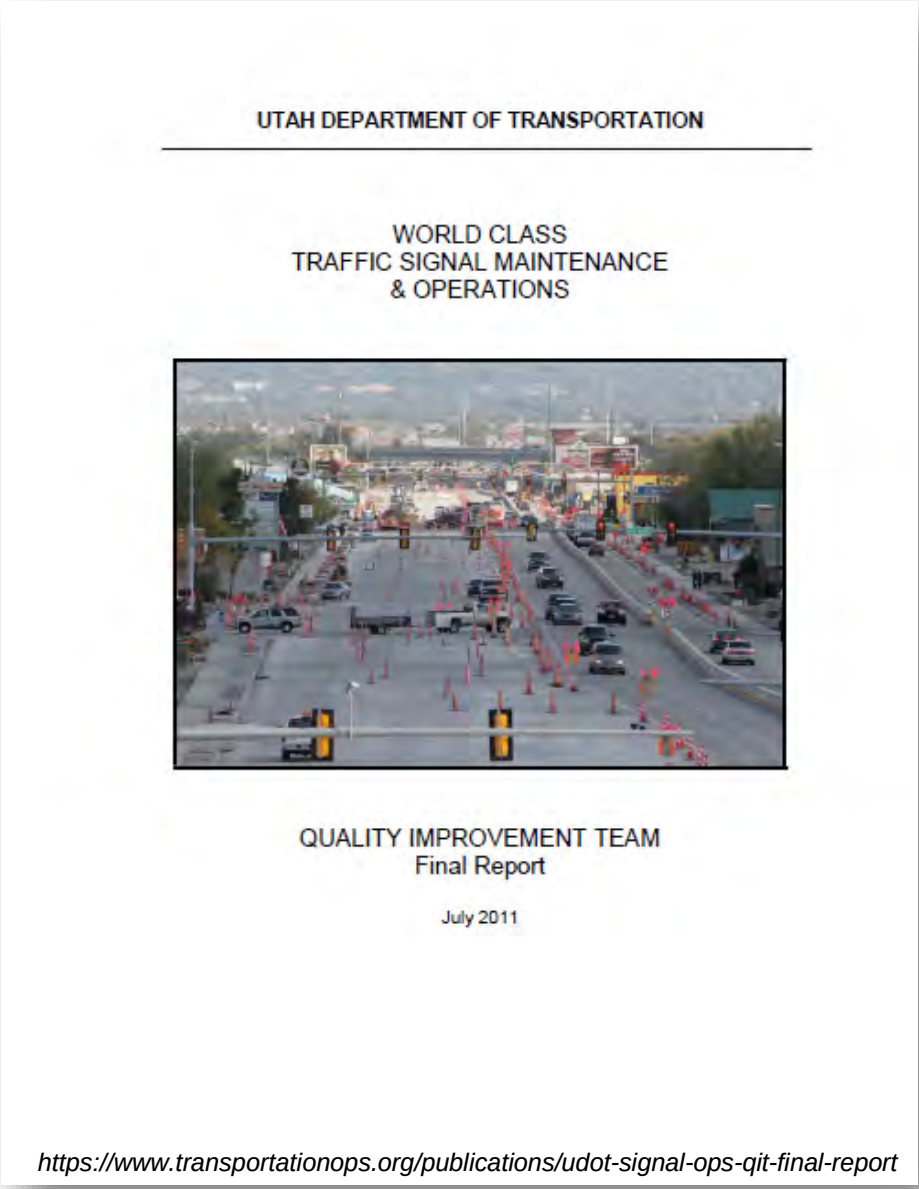
"What's the trend – are signal operations improving, staying the same or getting worse?"

"What are our areas of most need?"

Quality
Improvement
Team

QIT Recommendations
(July 2011)

- Communications and detection maintained during construction
- Proactive signal maintenance
- **Real-time monitoring of system health and quality of operations**



https://www.transportationops.org/publications/udot-signal-ops-qit-final-report

PERFORMANCE MEASURES FOR TRAFFIC SIGNAL SYSTEMS

An Outcome-Oriented Approach

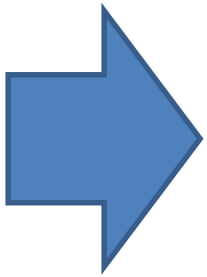
Christopher M. Day, Darcy M. Bullock, Howell Li, Stephen M. Remias, Alexander M. Hainen, Richard S. Freije, Amanda L. Stevens, James R. Sturdevant, and Thomas M. Brennan

http://docs.lib.purdue.edu/jtrpaffdocs/3/

Automated Traffic Signal Performance Measures (ATSPM) Basic Concept

Automated Data Collection

- Signal controller
- Probe source



Useful Information about Performance

- Signal
- Corridor
- System

Why Model what you can Measure?

Standard Controller Enumerations

http://docs.lib.purdue.edu/jtrpdata/3/

11-2012

Indiana Traffic Signal Hi Resolution Data Logger Enumerations

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Timothy Overman
INDOT

Eric Raamot
Econolite Group Inc.

Ray Deer
Peek Traffic Corporation

Dave Miller
Siemens Industry, Inc.

See next page for additional authors

Standard Controller Enumerations

Active Phase Events:

0	Phase On
1	Phase Begin Green
2	Phase Check
3	Phase Min Complete
4	Phase Gap Out
5	Phase Max Out
6	Phase Force Off
7	Phase Green Termination
8	Phase Begin Yellow Clearance
9	Phase End Yellow Clearance
10	Phase Begin Red Clearance
11	Phase End Red Clearance

Preemption Events:

101	Preempt Advance Warning Input
102	Preempt (Call) Input On
103	Preempt Gate Down Input Received
104	Preempt (Call) Input Off
105	Preempt Entry Started

Detector Events:

81	Detector Off
82	Detector On
83	Detector Restored
84	Detector Fault- Other
85	Detector Fault- Watchdog Fault
86	Detector Fault- Open Loop Fault

High-resolution Data Example

0.1-second resolution

Timestamp	Event Code	Event Parameter
6/27/2013 1:29:51.1	10	8
6/27/2013 1:29:51.1	82	5
6/27/2013 1:29:52.2	1	2
6/27/2013 1:29:52.2	1	6
6/27/2013 1:29:52.3	82	2
6/27/2013 1:29:52.8	82	4
6/27/2013 1:29:52.9	81	4
6/27/2013 1:29:54.5	81	2
6/27/2013 1:30:02.2	8	2
6/27/2013 1:30:02.2	8	6
6/27/2013 1:30:06.1	10	2
6/27/2013 1:30:06.1	10	6
6/27/2013 1:30:08.1	1	8
6/27/2013 1:30:15.8	81	5
6/27/2013 1:30:18.5	82	6
6/27/2013 1:30:27.5	81	6
6/27/2013 1:30:30.4	8	8

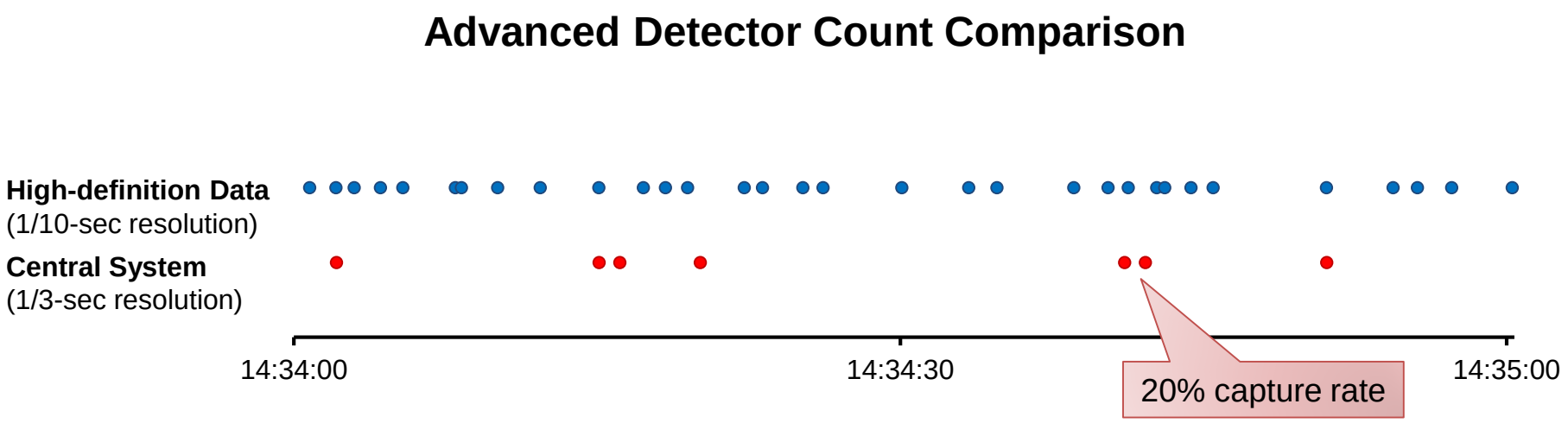
Detector 5 ON

Phase 8 GREEN

Detector 5 OFF

Phase 8 YELLOW

Why is High-resolution Data Important?



ATSPM System Architecture

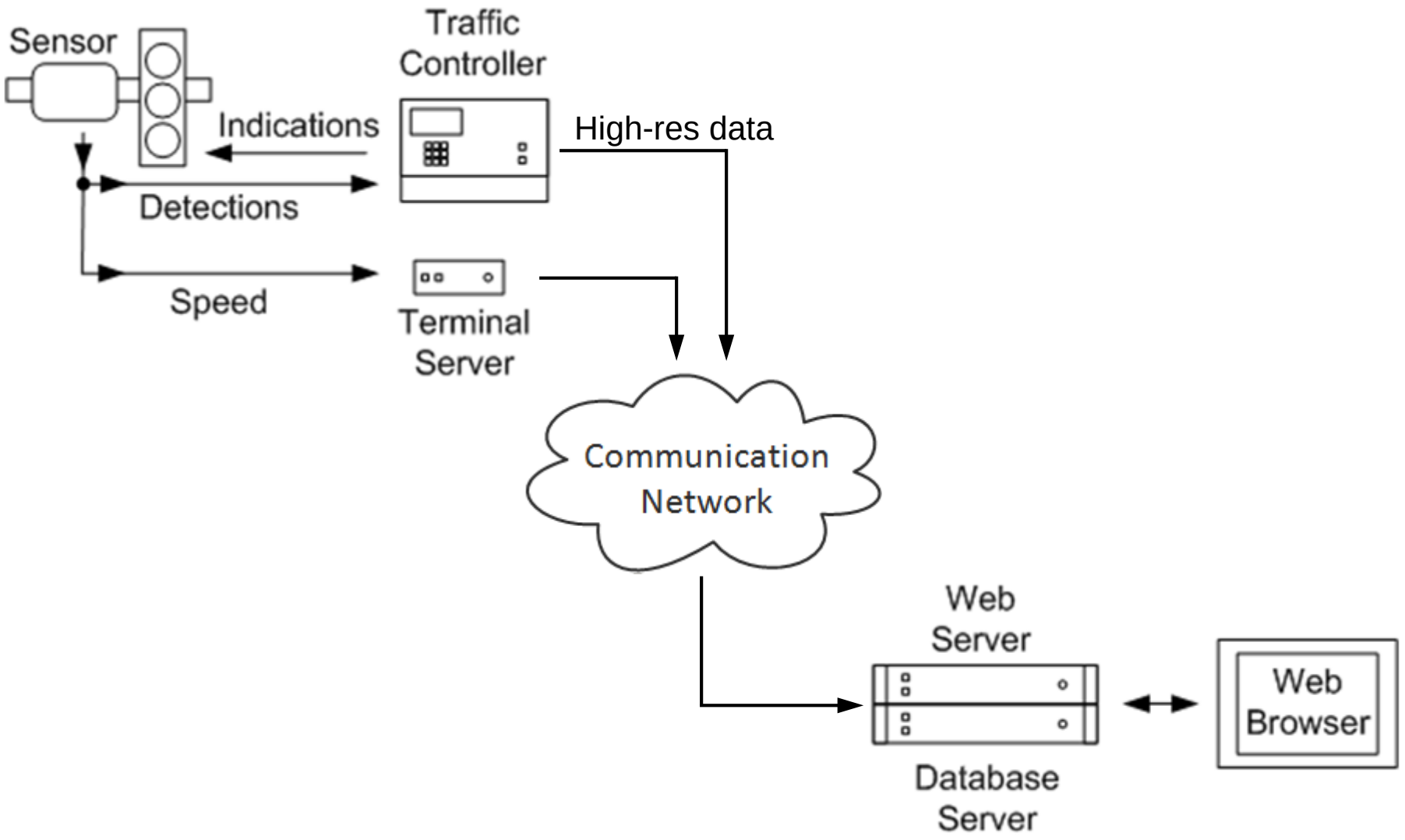


Image courtesy of Wavetronix

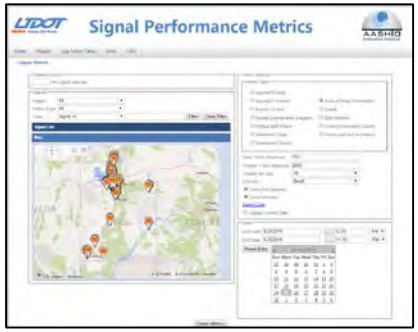
System Requirements

High-resolution Controller
(or stand-alone data aggregator)

Communications

1) Get *.dat* Files
2) Translate Files
   .dat → *.csv*
3) Store in Database

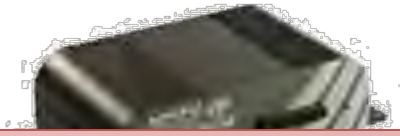
Server



Software

Detection
(optional)

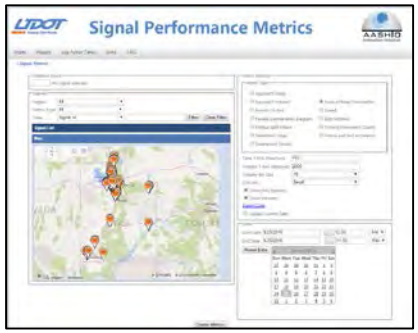
System Requirements



Does NOT require
Central Traffic Management Software!

1) Get *.dat* Files
2) Translate Files
   .dat → *.csv*
3) Store in Database

Server



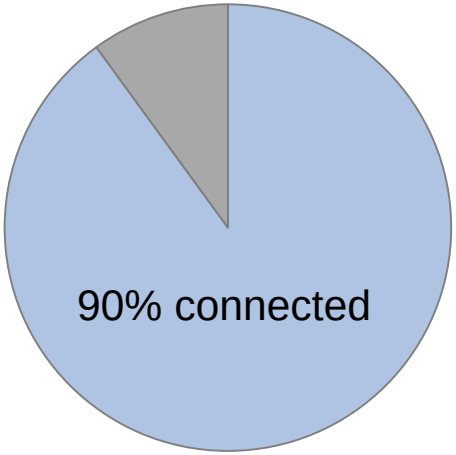
Software

Detection
(optional)

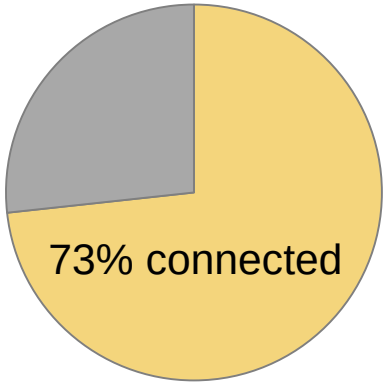
Vendor Neutrality

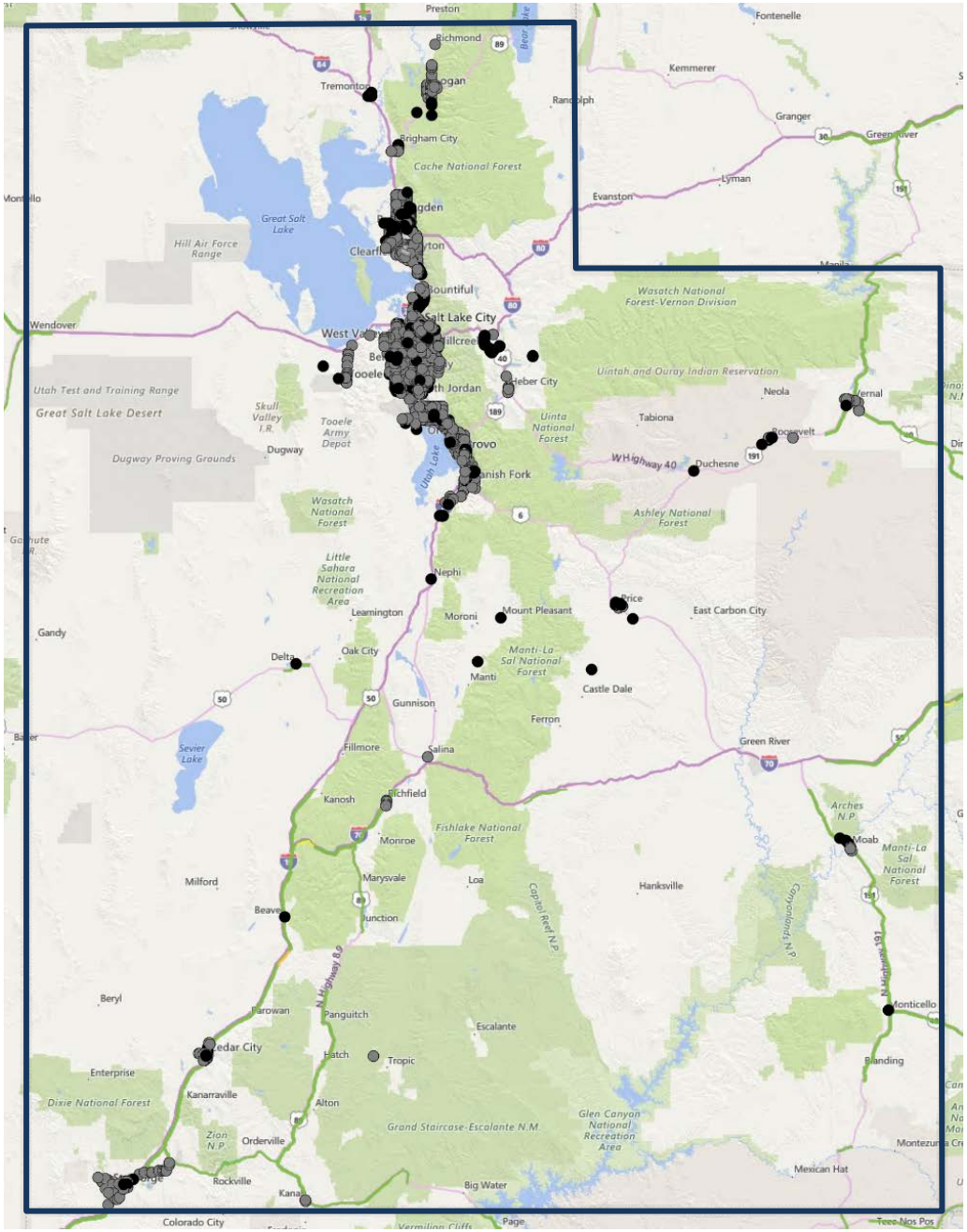
Traffic Signals in Utah

UDOT Signals: 1237



Partner Signals: 887

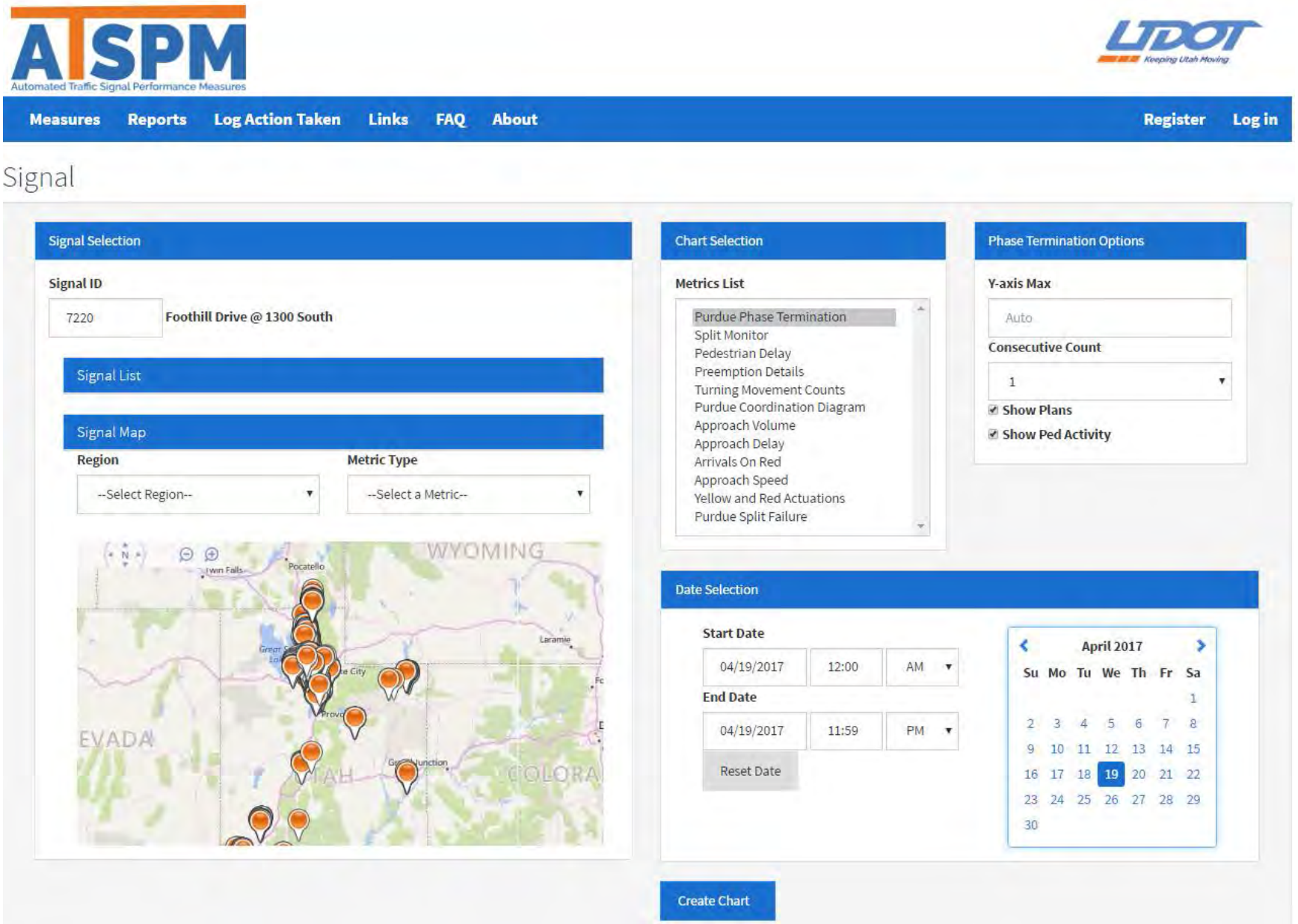




Signals without Communication

UDOT's ATSPM Website

http://udottraffic.utah.gov/ATSPM



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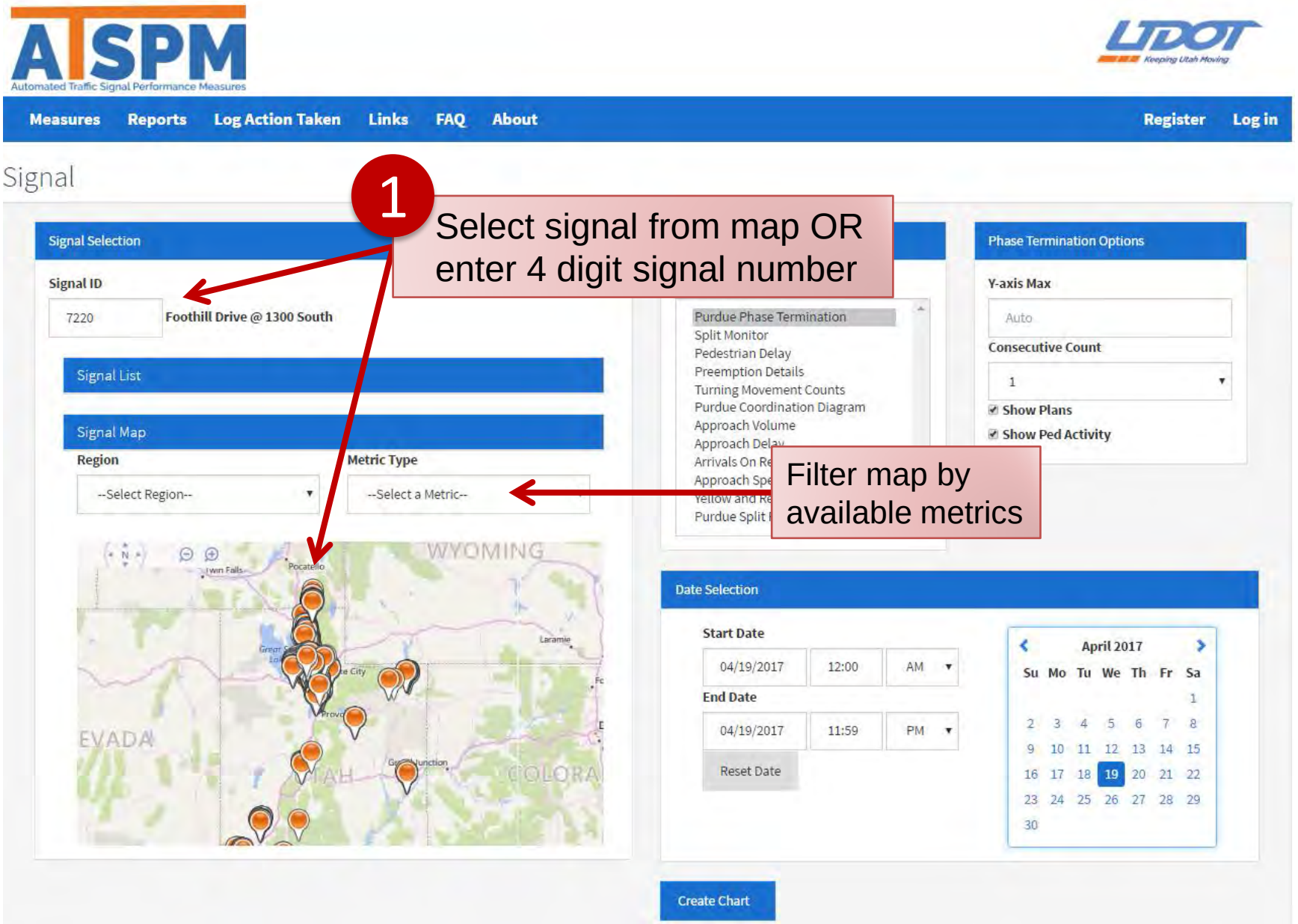

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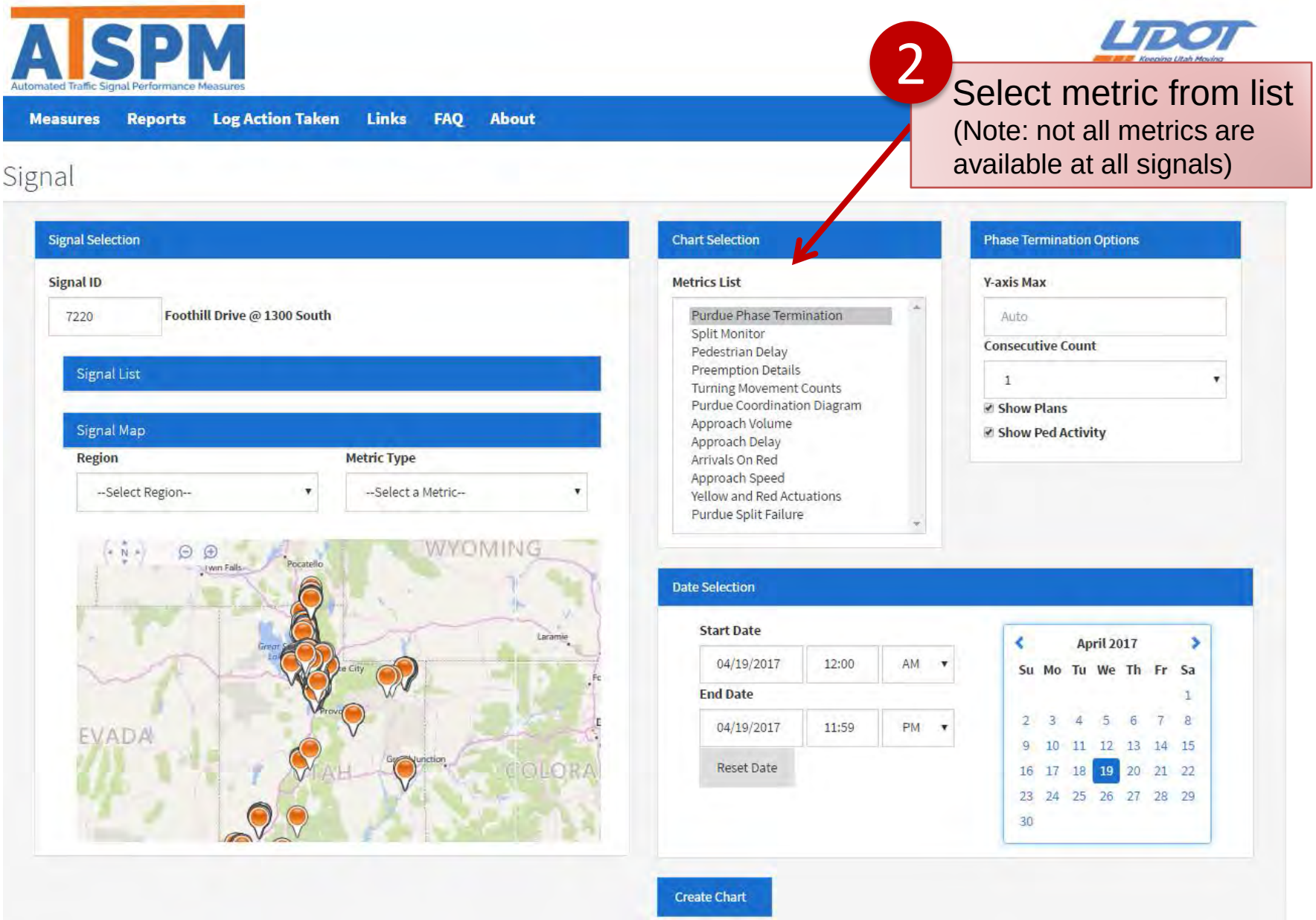

UDOT's ATSPM Website

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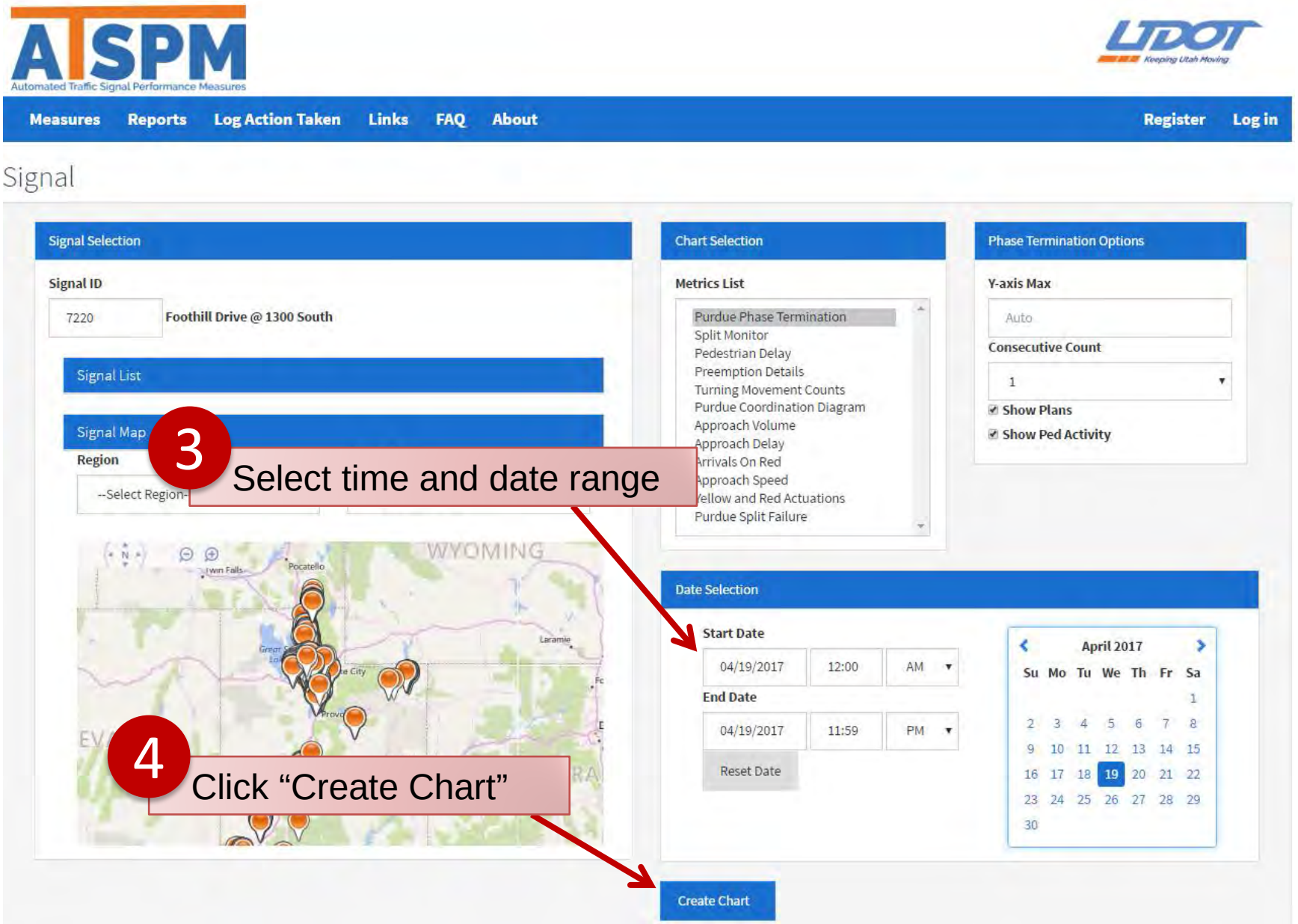
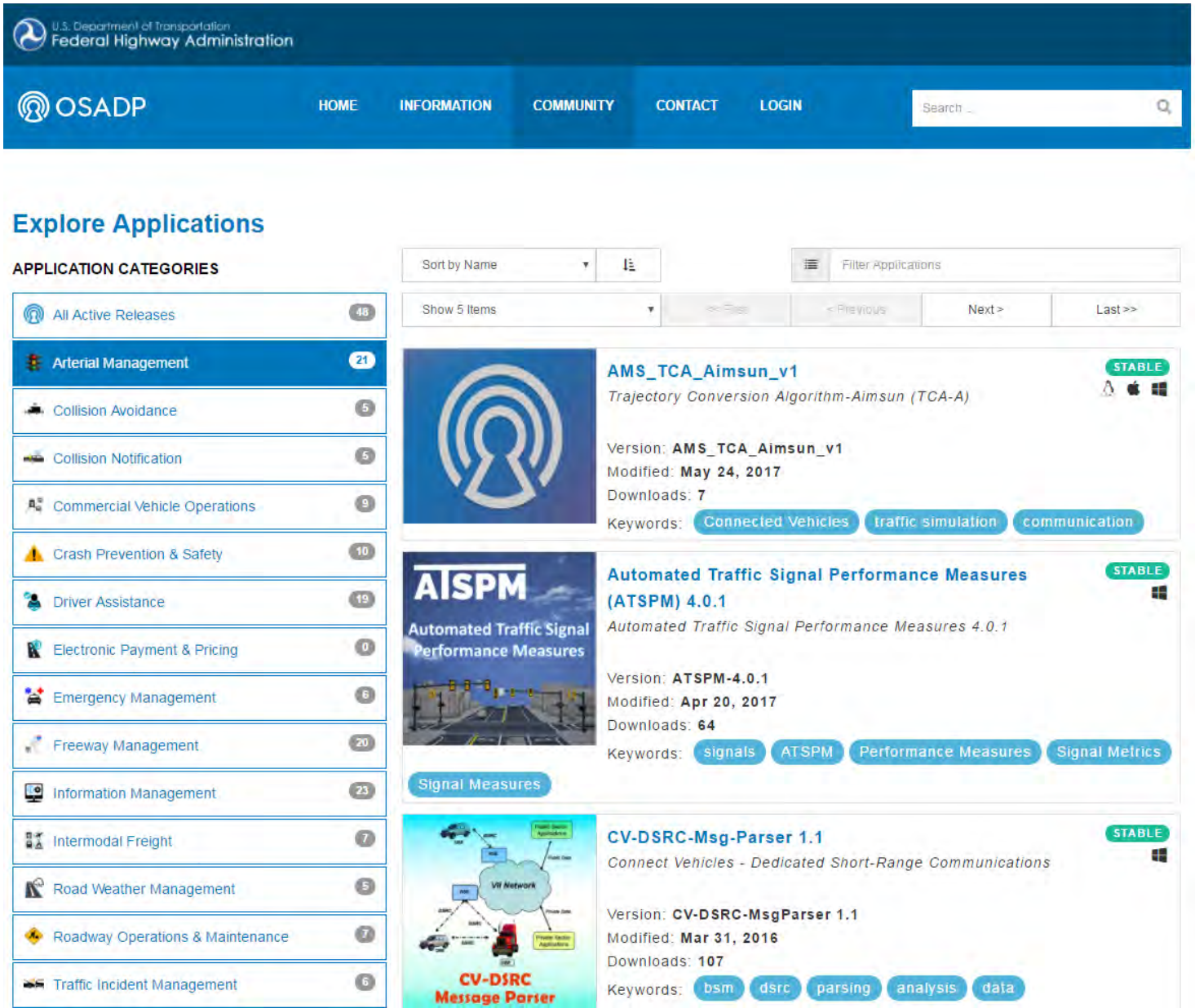


UDOT ATSPM Source Code

https://www.itsforge.net



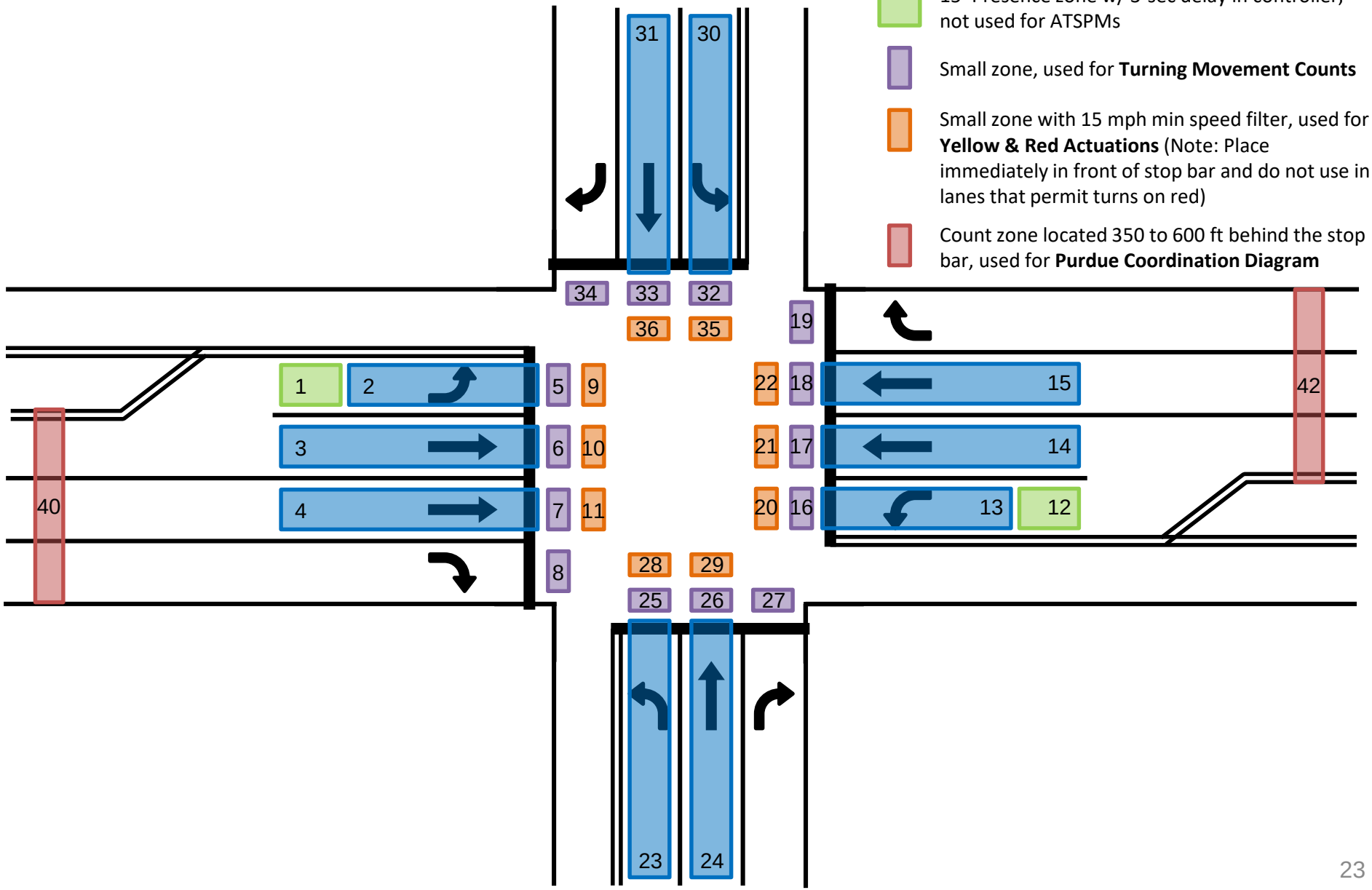
UDOT ATSPM Implementation Cost

	Small System (~50 signals)	**Large System** (~1000 signals)
Controllers w/ High-definition Loggers	Unknown	Unknown
Communication or In-cabinet Data Storage	Unknown	Unknown
UDOT ATSPM Software	$0	$0
Server	$3,000	$20,000
SQL Database License	$7,000	$100,000
IT Consultant	$5,000	$10,000
Engineering Consultant (detector configuration)	$5,000	$100,000
Total	$20,000	$230,000
Cost per signal	*$400*	*$230*

DETECTION

UDOT Automated Traffic Signal Performance Measures

UDOT Full Detection Setup

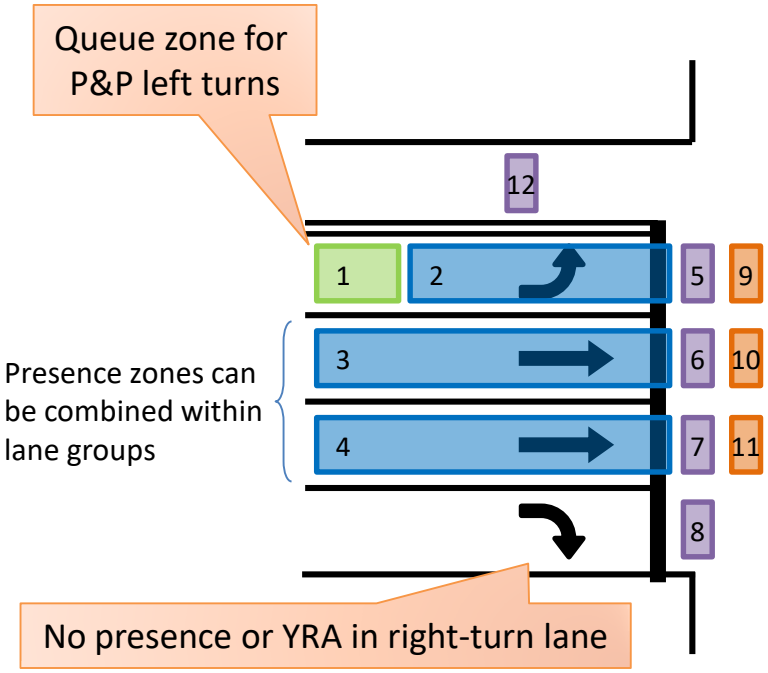


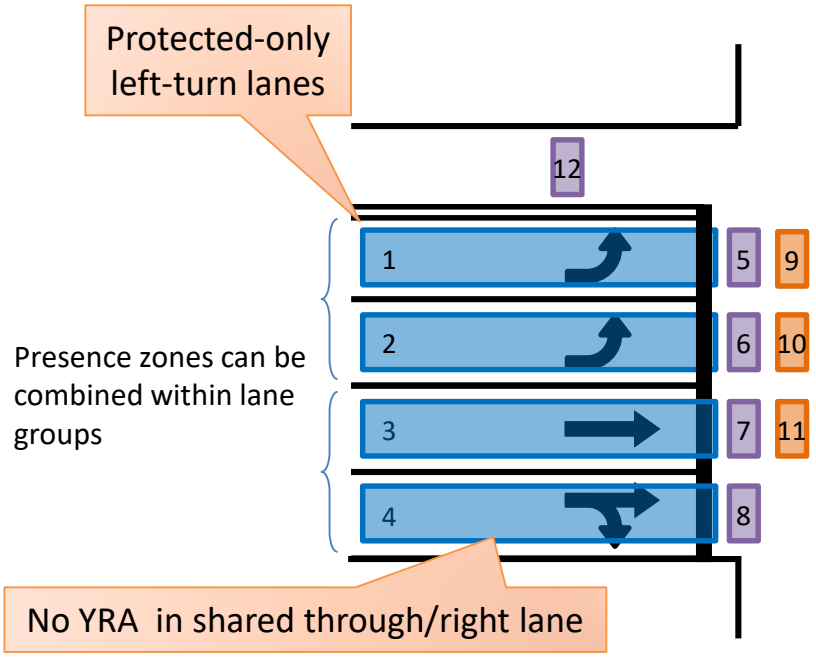
Turning Movement Counts Detection

Wavetronix
SmartSensor
Matrix

Wavetronix
Cabinet Interface Device
Click 650

Wavetronix Matrix – Standard Detection Layout w/ Click 650





Detection Channel Order

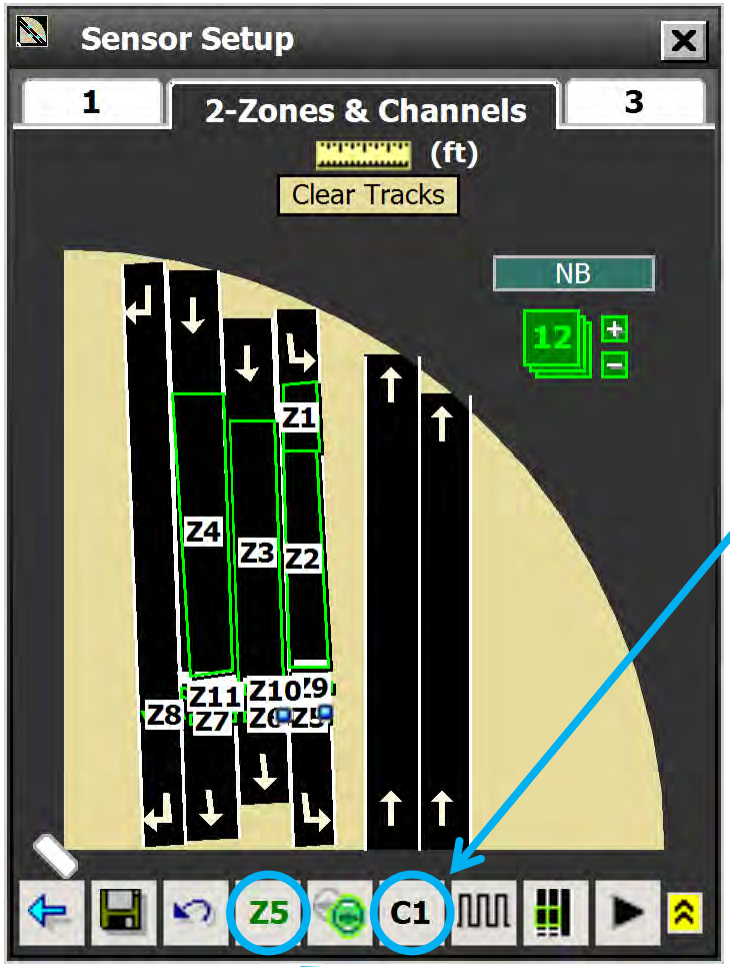
1. Presence zones, inside to outside. If P&P zones, the queue zone is first.
2. Count channels, inside to outside
3. YRA zones, inside to outside
4. Count zones in exit lanes, inside to outside *(often skipped)*

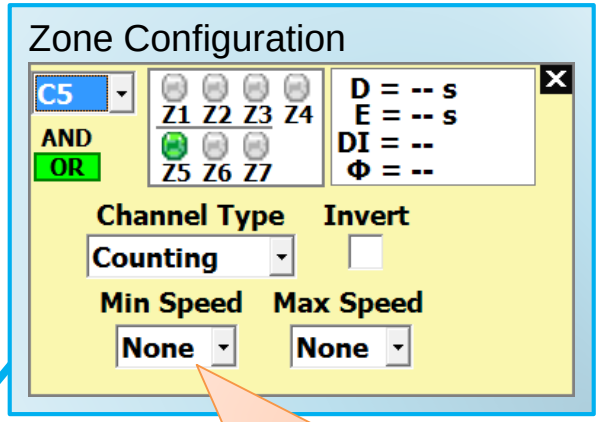
Matrix Sensor Order

1. Phase 2
2. Phase 6
3. Phase 4
4. Phase 8

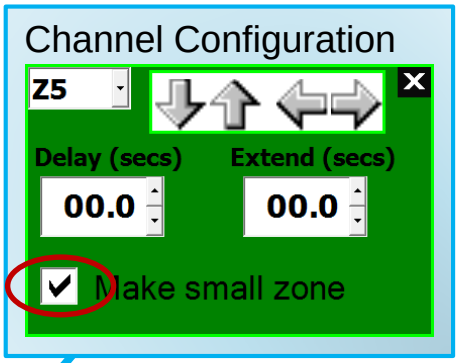
- 65’ or 50’ Presence zone, used for **Split Failure**
- 15’ Presence zone w/ 3-sec delay in controller, not used for ATSPMs
- Small zone, used for **Turning Movement Counts**
- Small zone with 15 mph min speed filter, used for **Yellow & Red Actuations** (Note: Place immediately in front of stop bar and do not use in lanes that permit turns on red)

Wavetronix Matrix – Configuration for Turning Movement Counts





Min Speed = 15 or 20 mph for Yellow & Red Actuations (YRA)



Approach Volume Detection

Wavetronix
SmartSensor
Advance

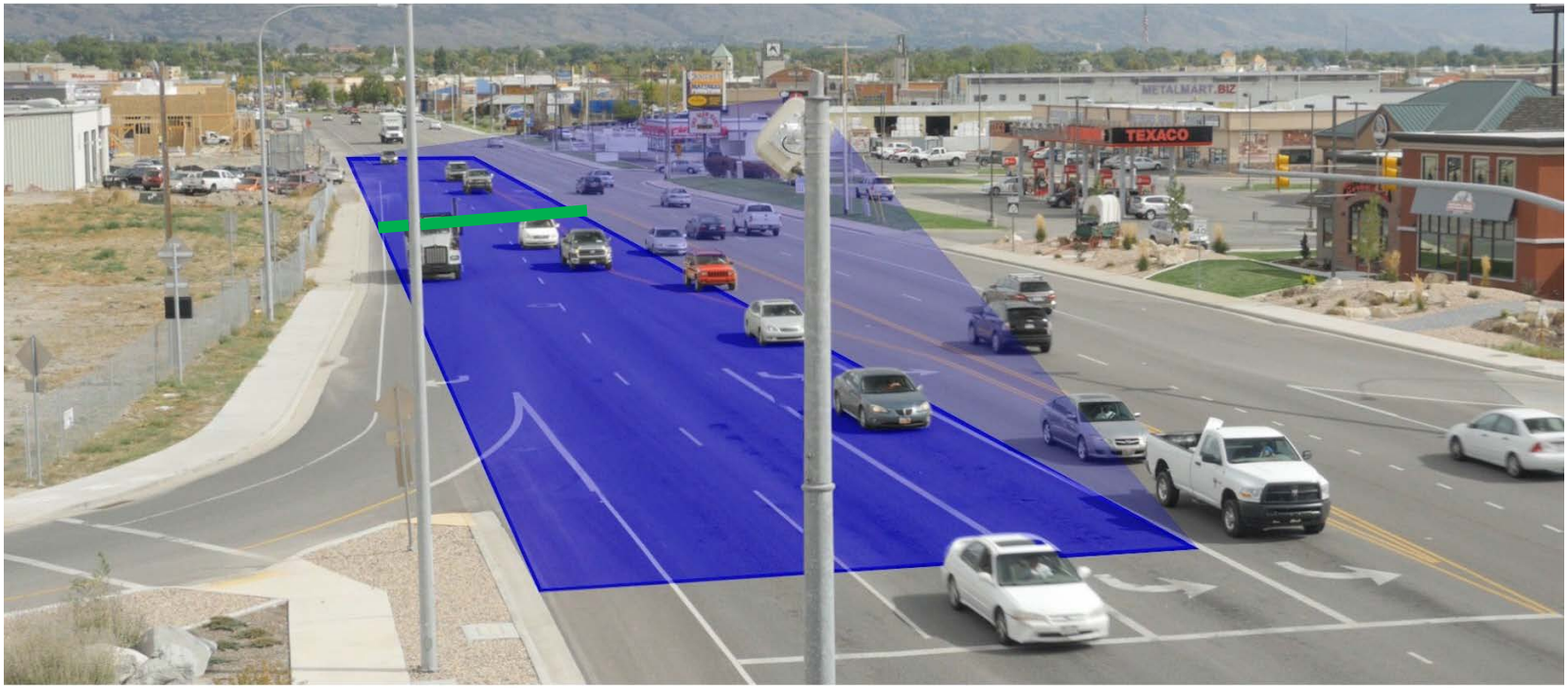
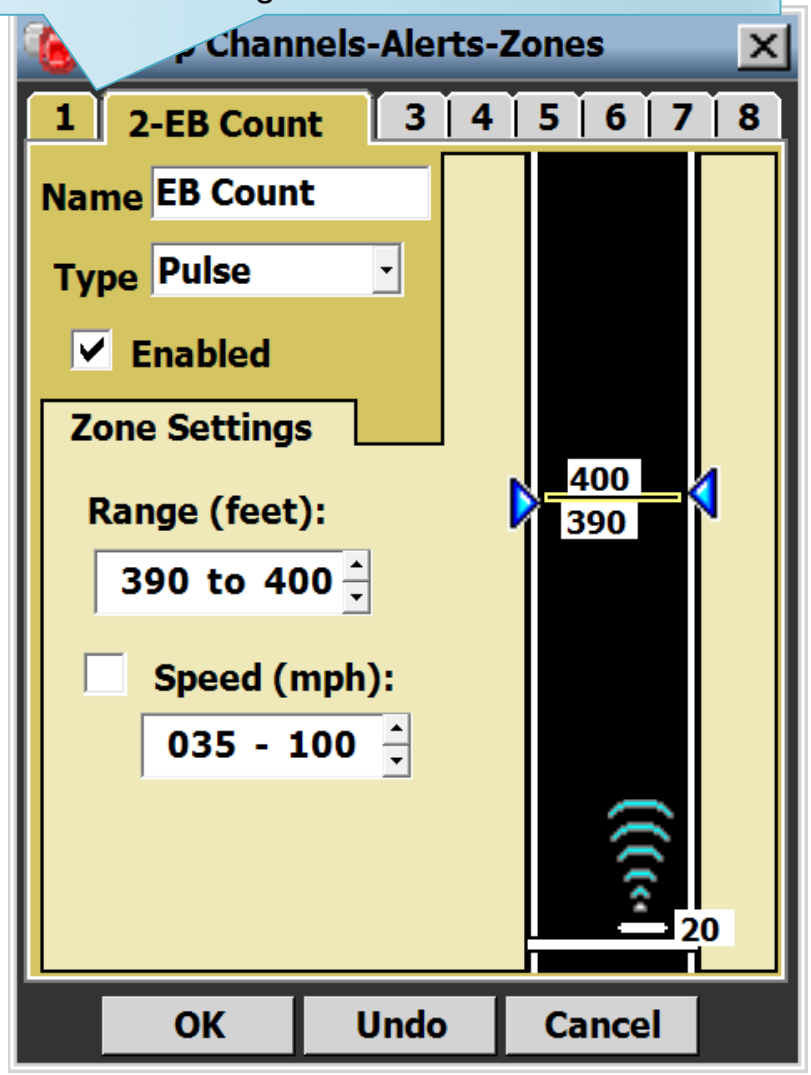
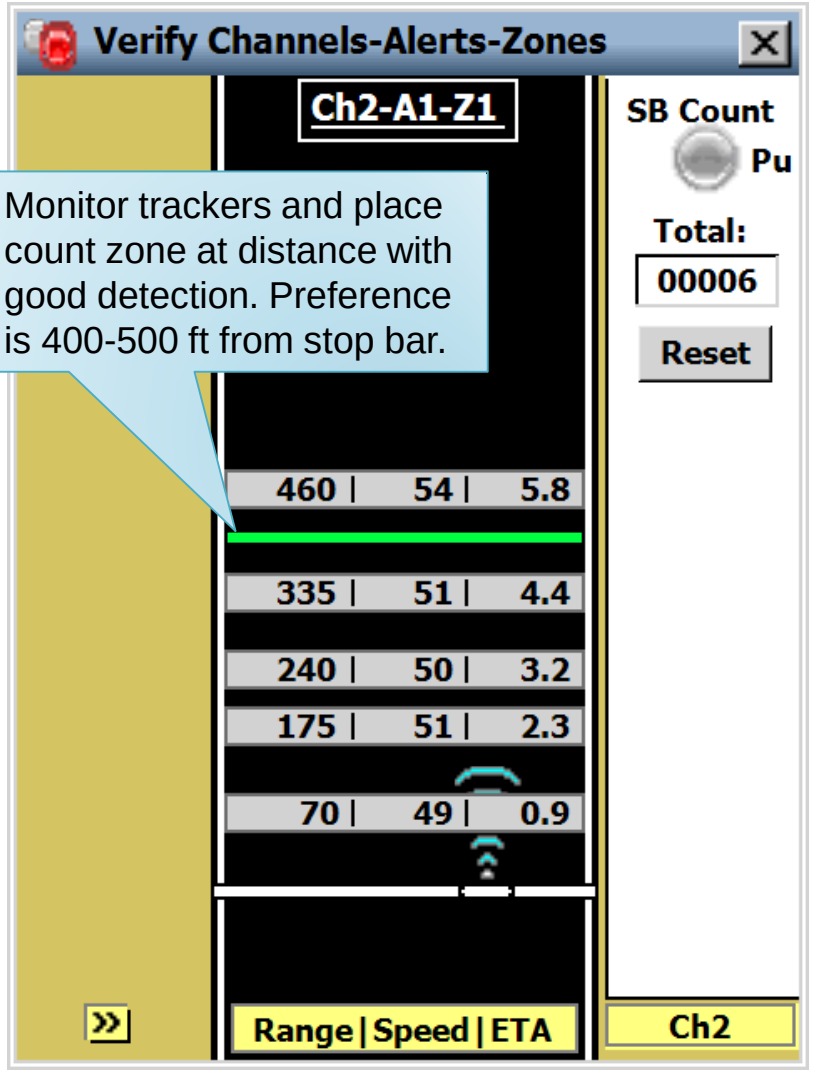


Image courtesy of Wavetronix

Wavetronix Advance Count Setup

Channel 1 – Dilemma Zone and Queue Clearance
Channel 2 – Counting

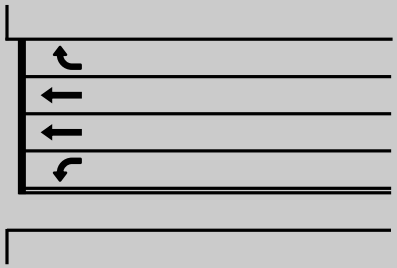
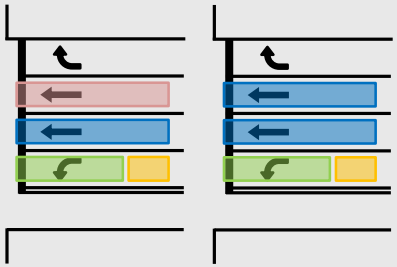
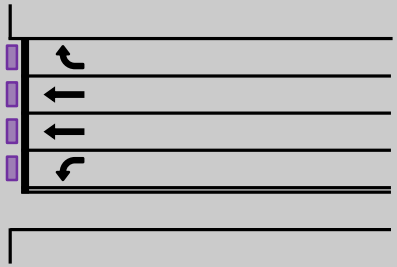




Monitor trackers and place count zone at distance with good detection. Preference is 400-500 ft from stop bar.

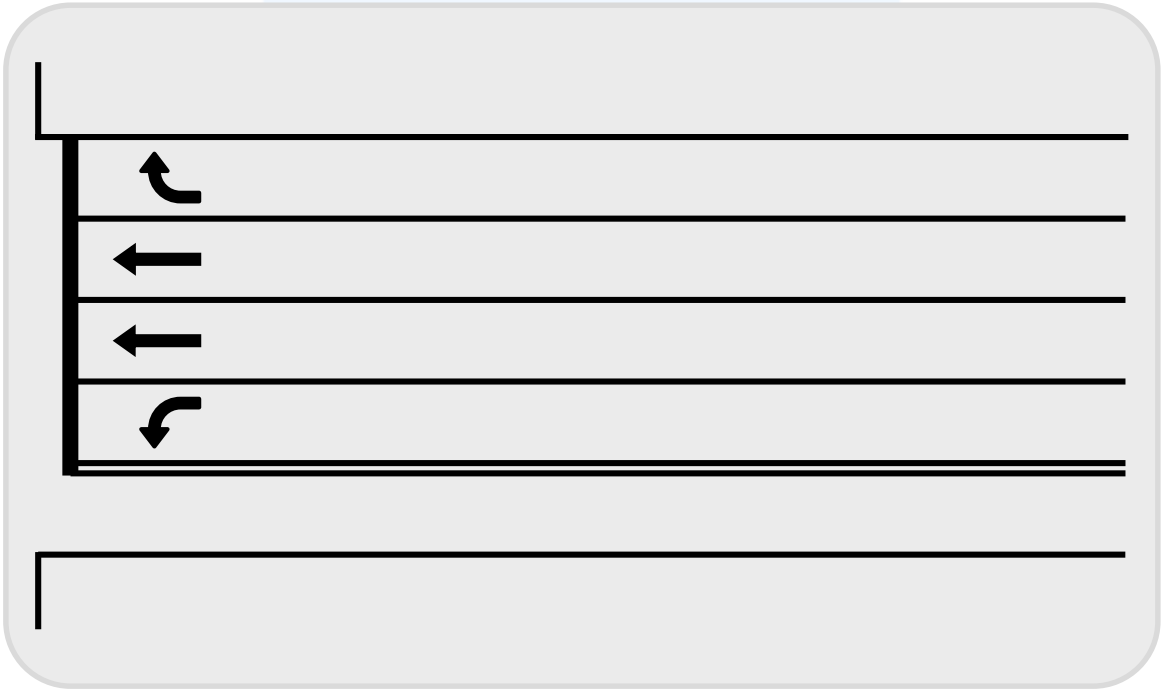
METRICS

UDOT Automated Traffic Signal Performance Measures

Detection	Metric
None 	Phase Termination Chart Split Monitor Preemption Details Pedestrian Delay
Lane-by-lane or Lane Group Presence 	Purdue Split Failure
Lane-by-lane Stop Bar Count 	Turning Movement Counts
Advanced Count 	Purdue Coordination Diagram Purdue Link Pivot Offset Optimization Approach Volume Approach Speed (requires detection with speed service)

Detection

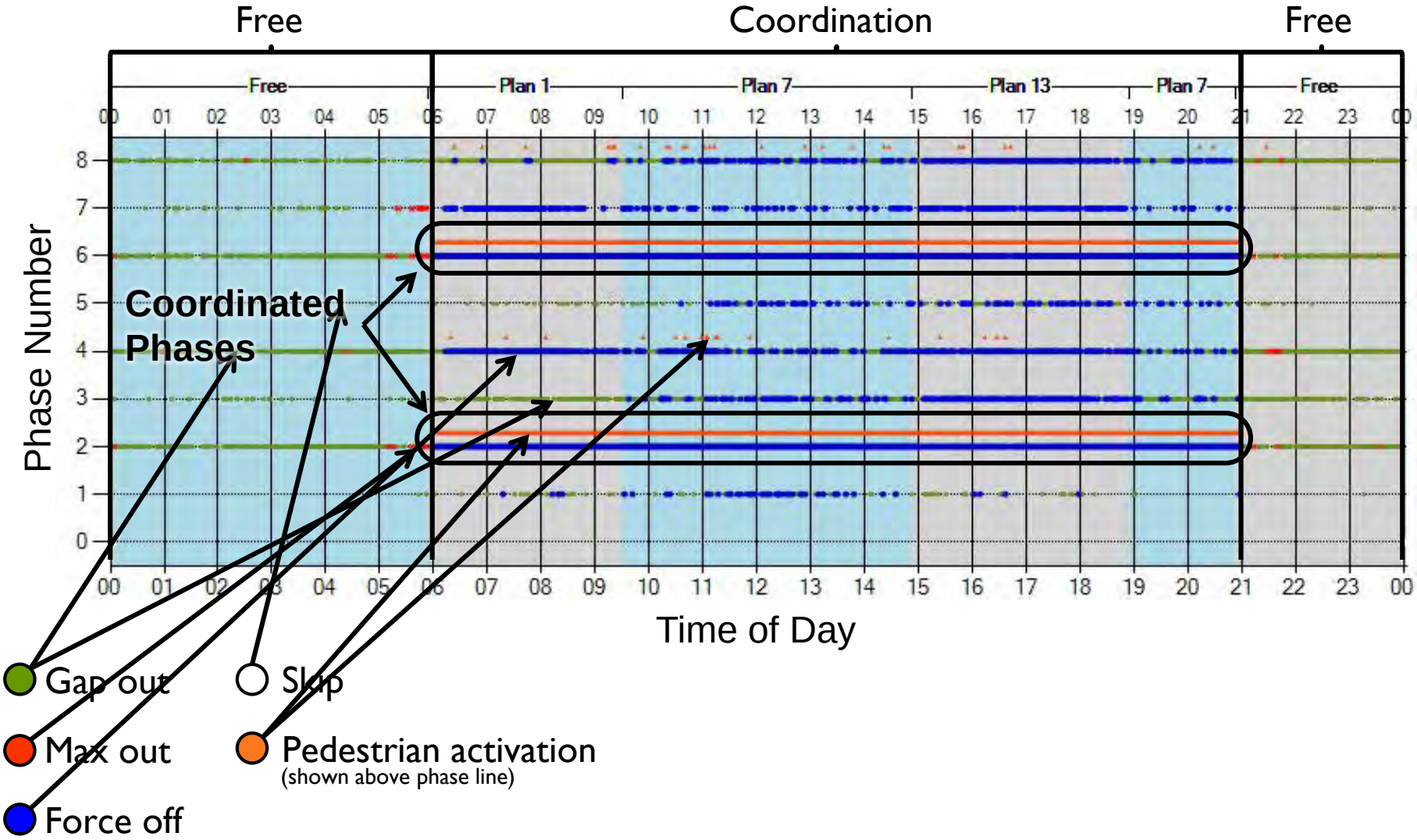
None



Available Metrics

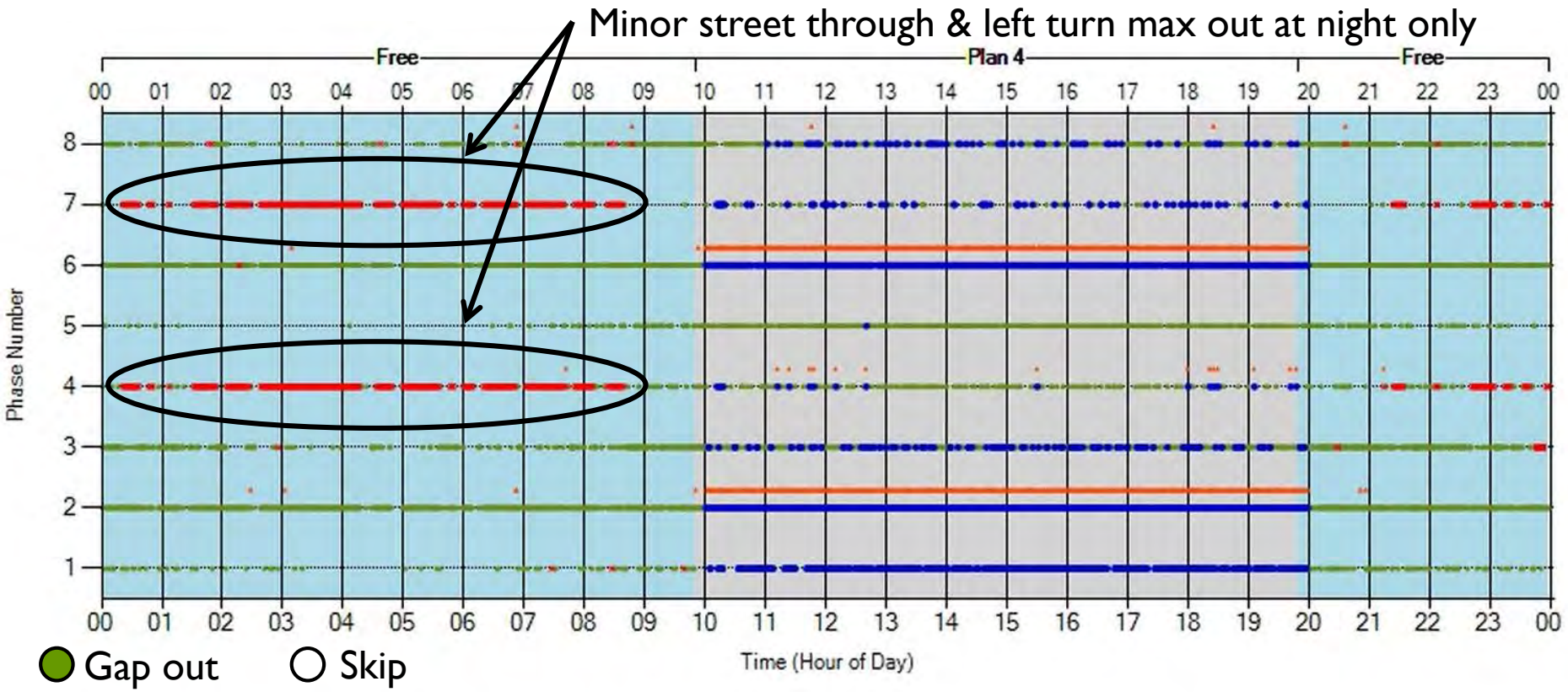
- Phase Termination Chart
- Split Monitor
- Pedestrian Delay
- Preemption Details

Metric: Phase Termination Chart



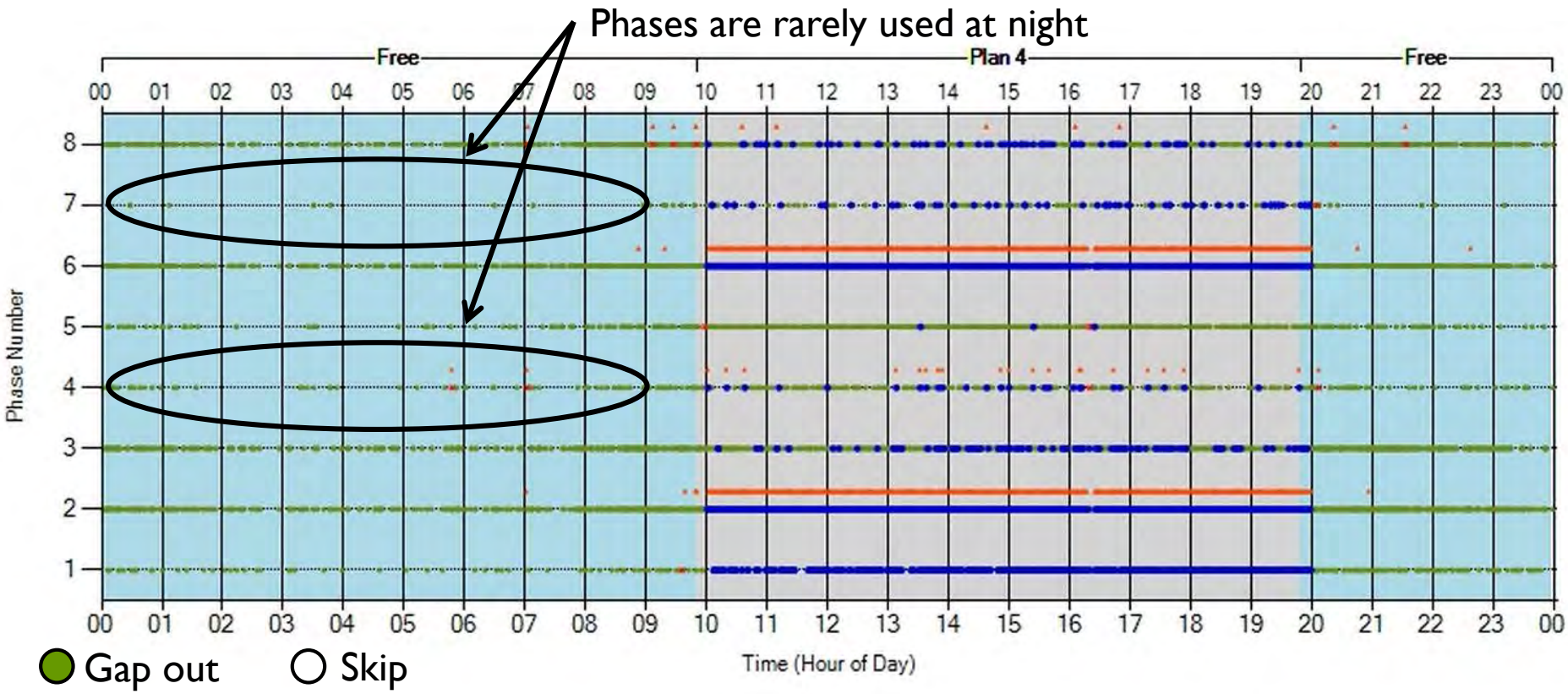
Complaint: Long main street red at 2 a.m.

Before Video detection not working at night

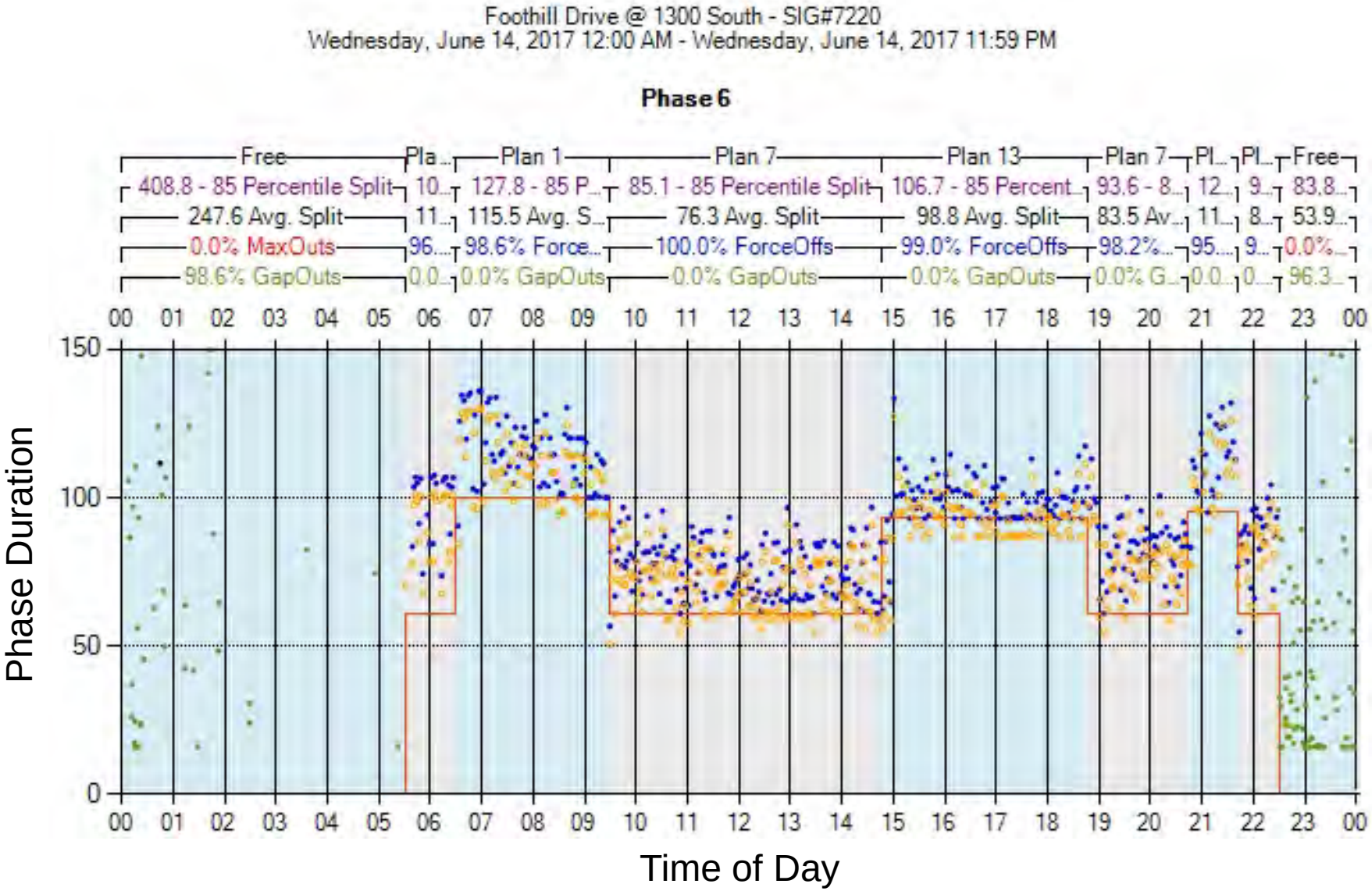


Complaint: Long main street red at 2 a.m.

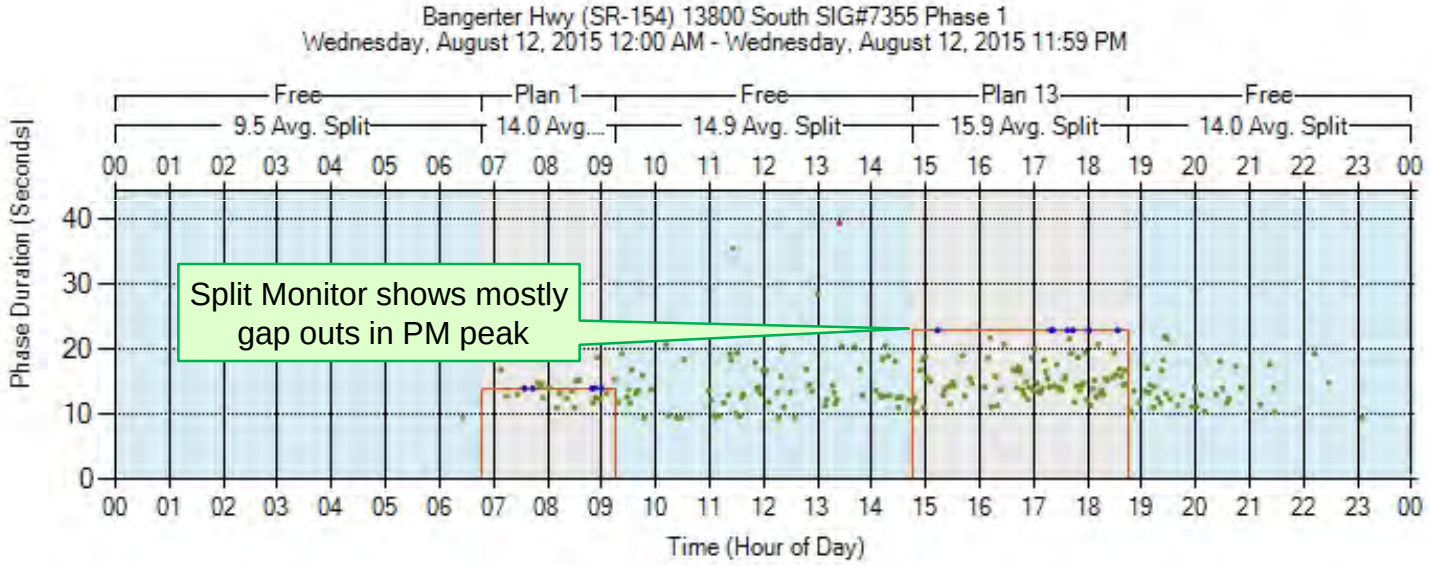
After New detection technology installed



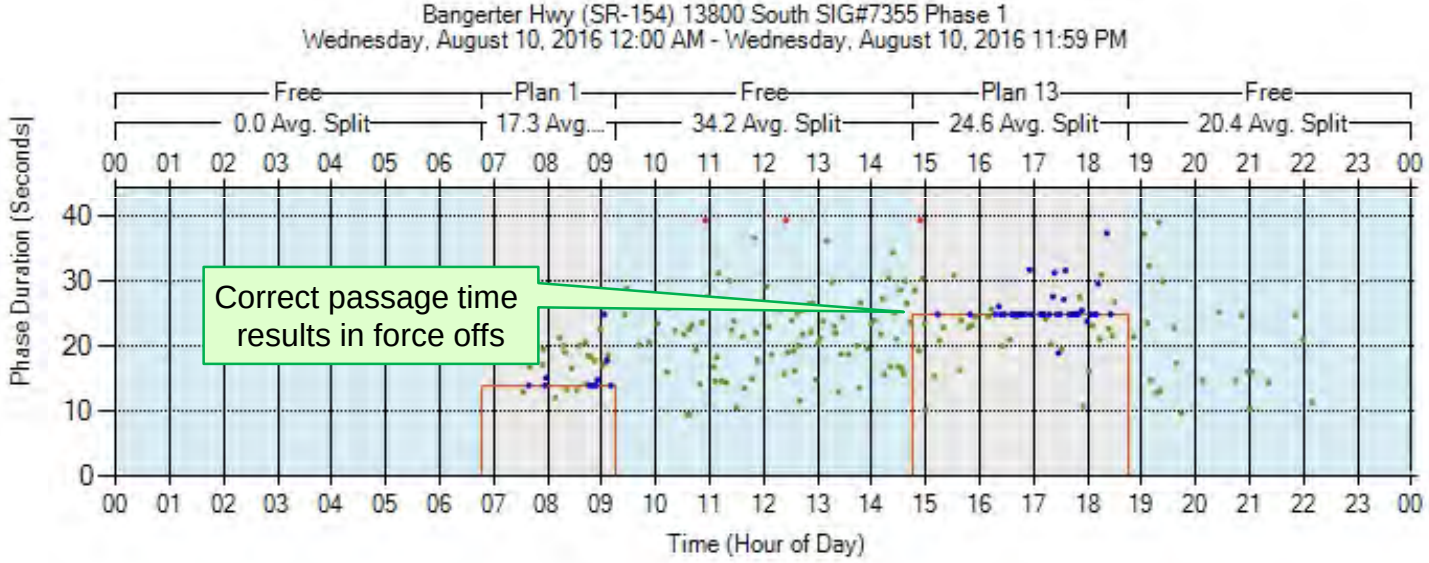
Metric: Split Monitor



Complaint: Long queue, short green, PM peak



Before



After

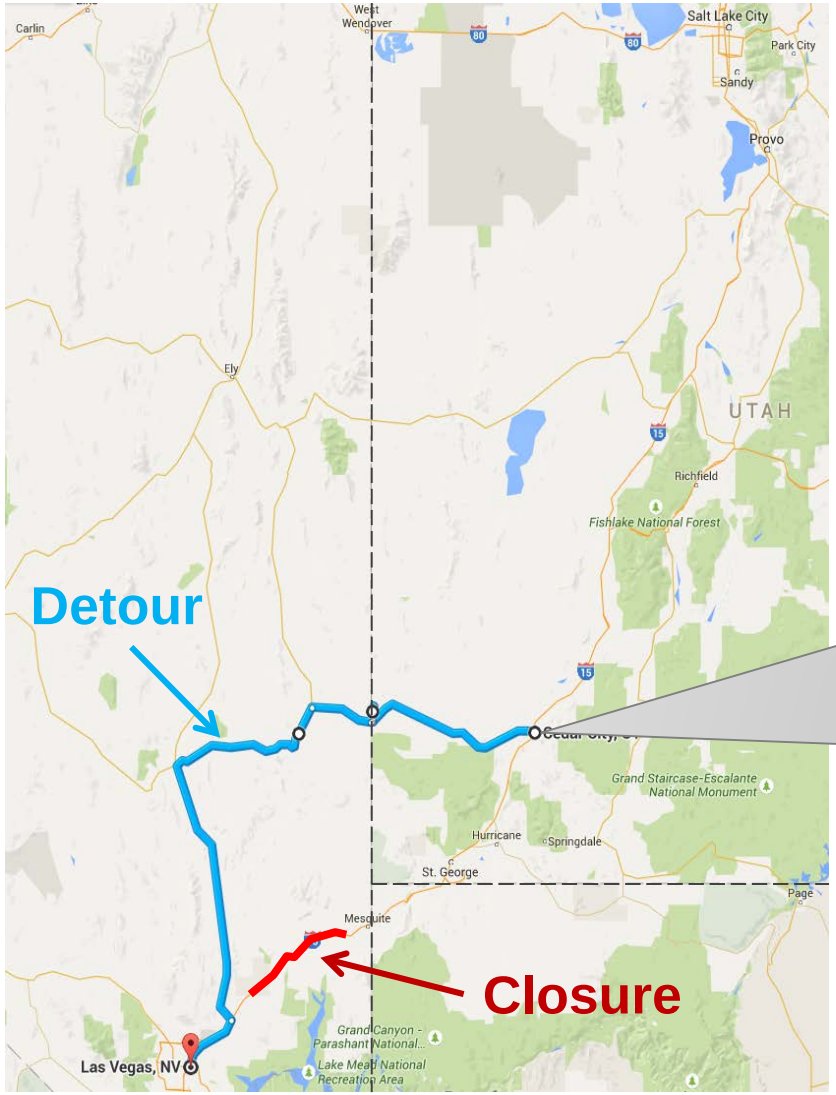
Example: I-15 Freeway Closure, September 9-12, 2014

Heavy rain rips apart I-15 in Nevada, forces freeway closure

By Ken Ritter, Michelle Rindels , Associated Press | Posted Sep 9th, 2014 @ 7:44pm

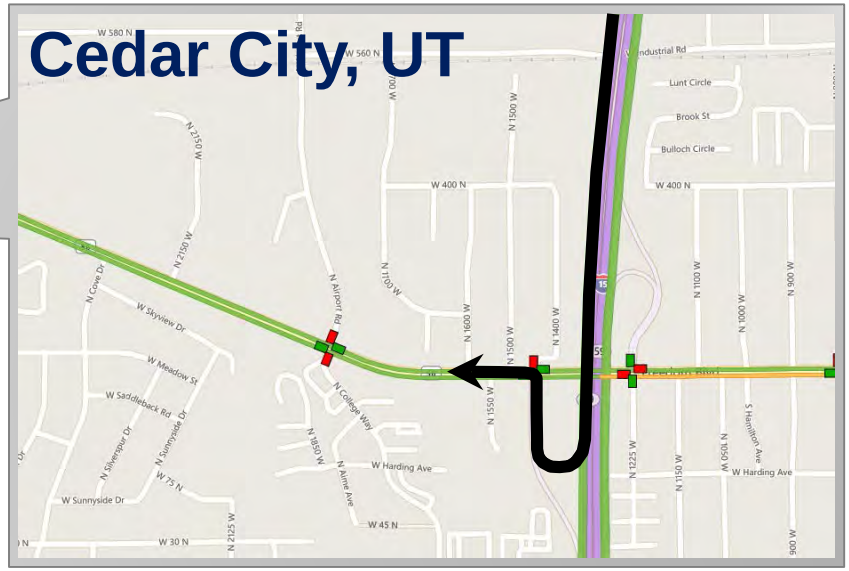
Source: KSL

Example: I-15 Freeway Closure, September 9-12, 2014

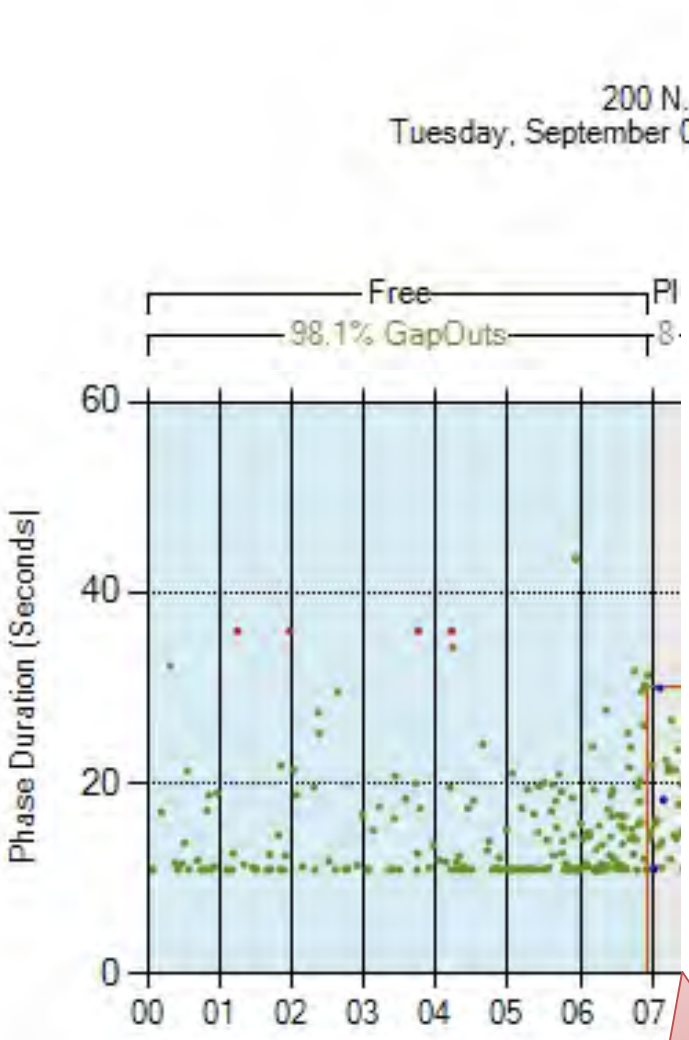


Southbound I-15 Closed in Nevada

- 4-day closure
- Detour to Las Vegas: Exit I-15 in Cedar City



Split Monitor for Incident Management

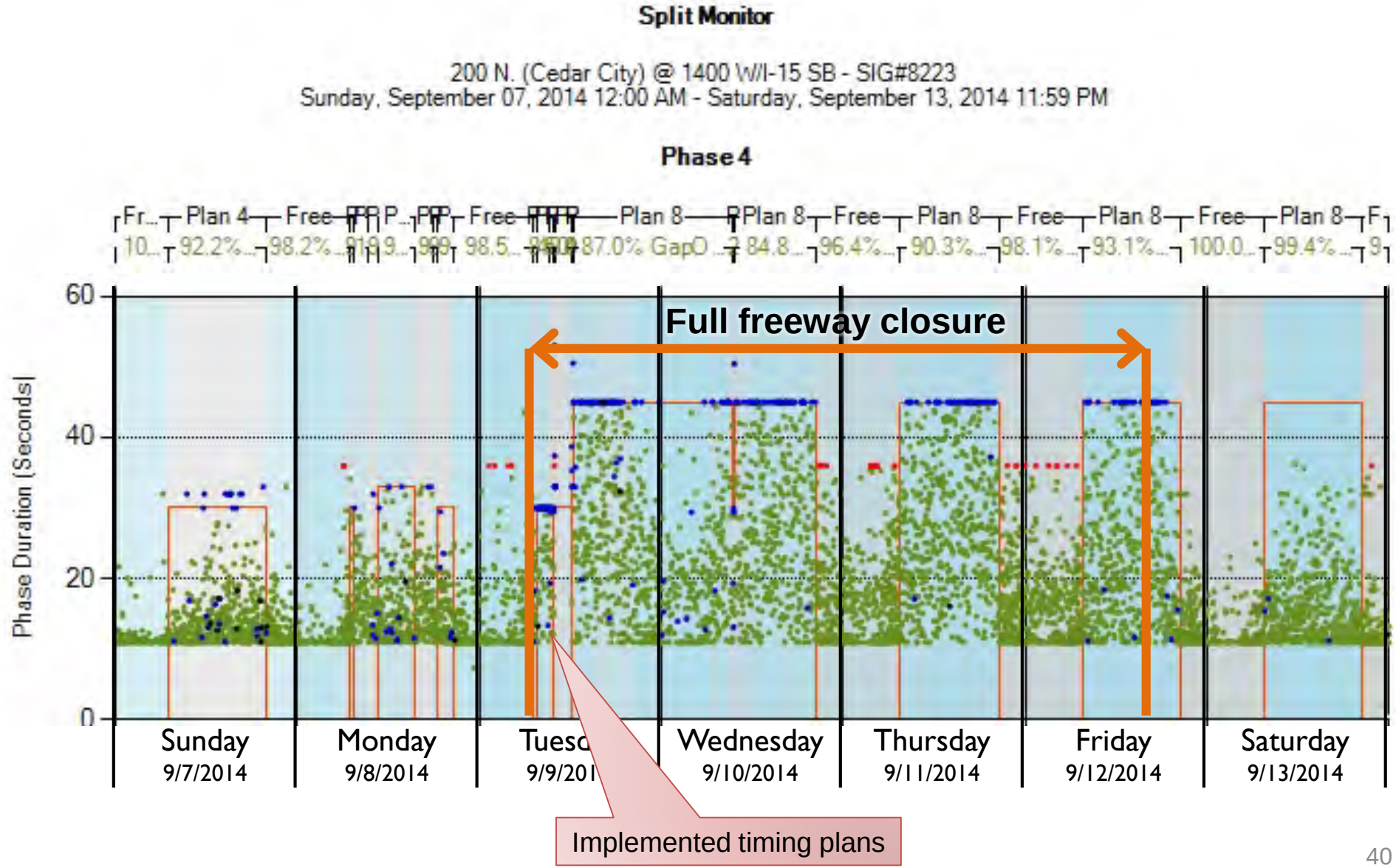


Revise Timing Plan for better % gap outs

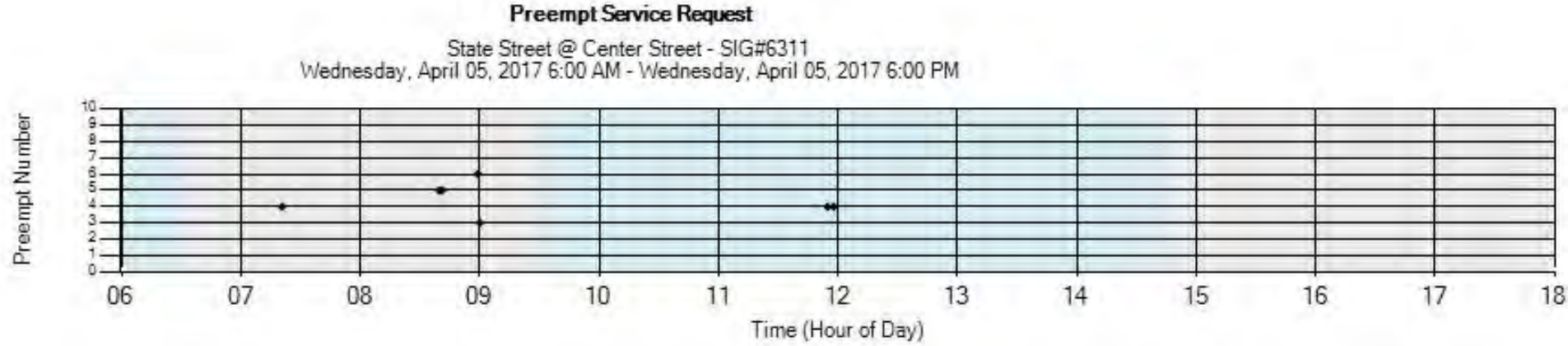
Detour starts

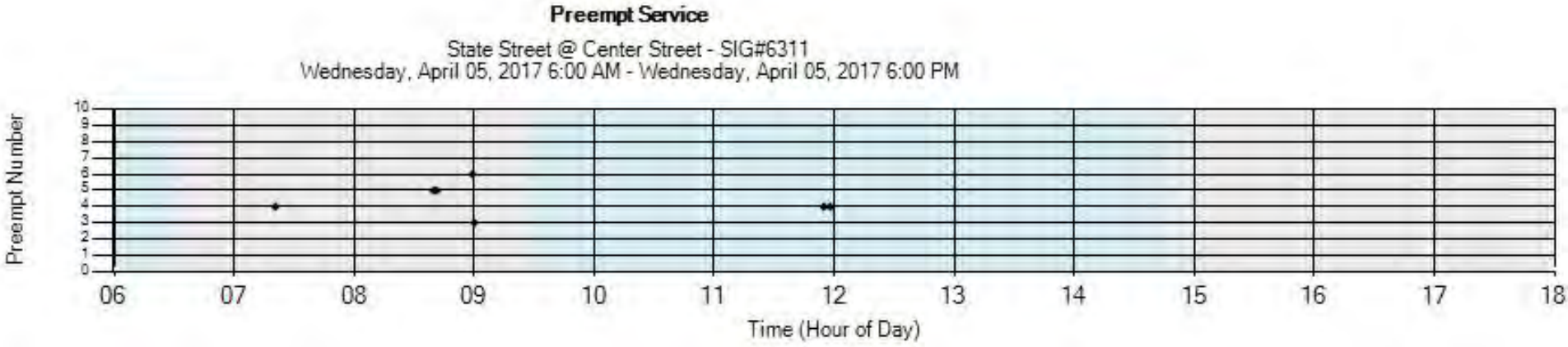
Implement Timing Plans

Split Monitor for Incident Management



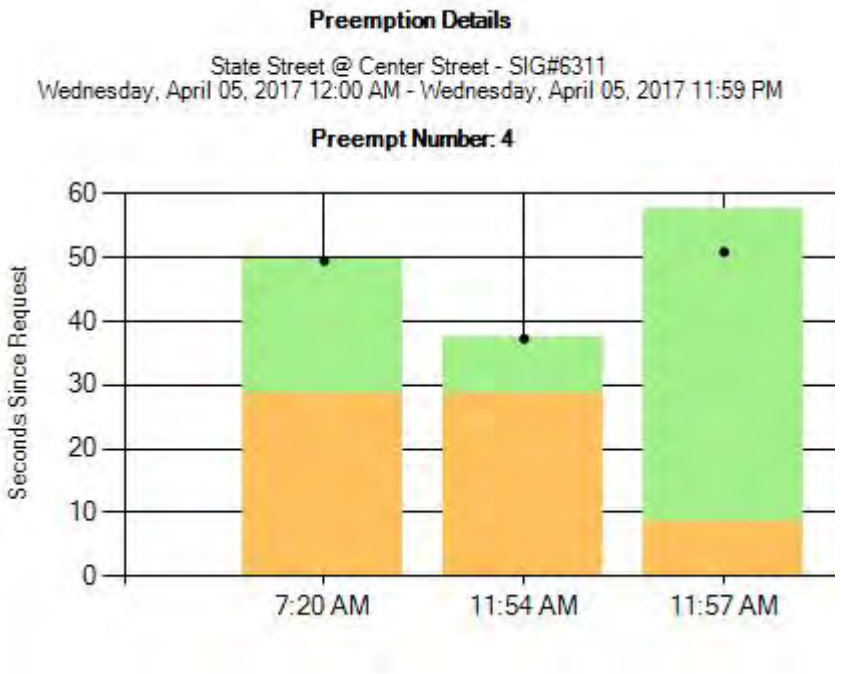
Metric: Preemption Details



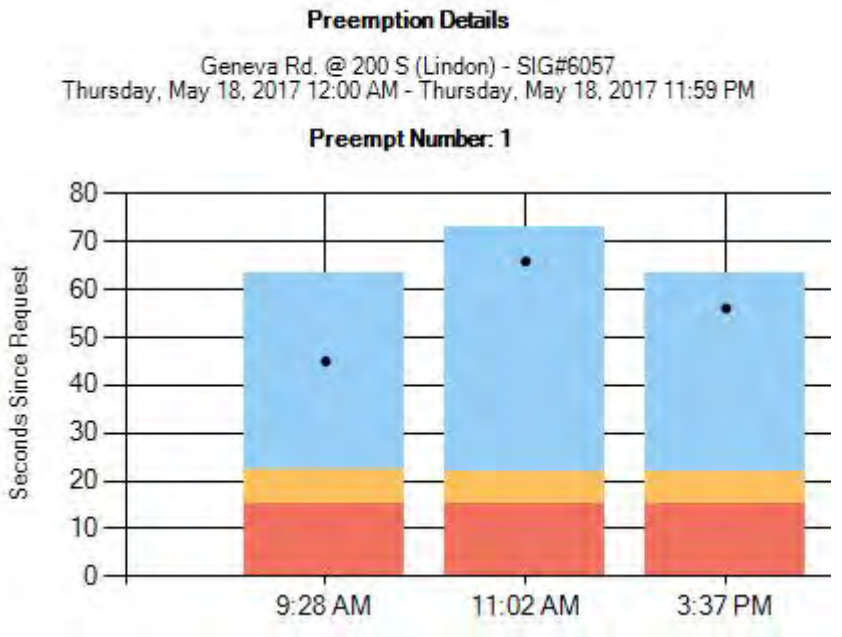


Metric: Preemption Details

Emergency Vehicle

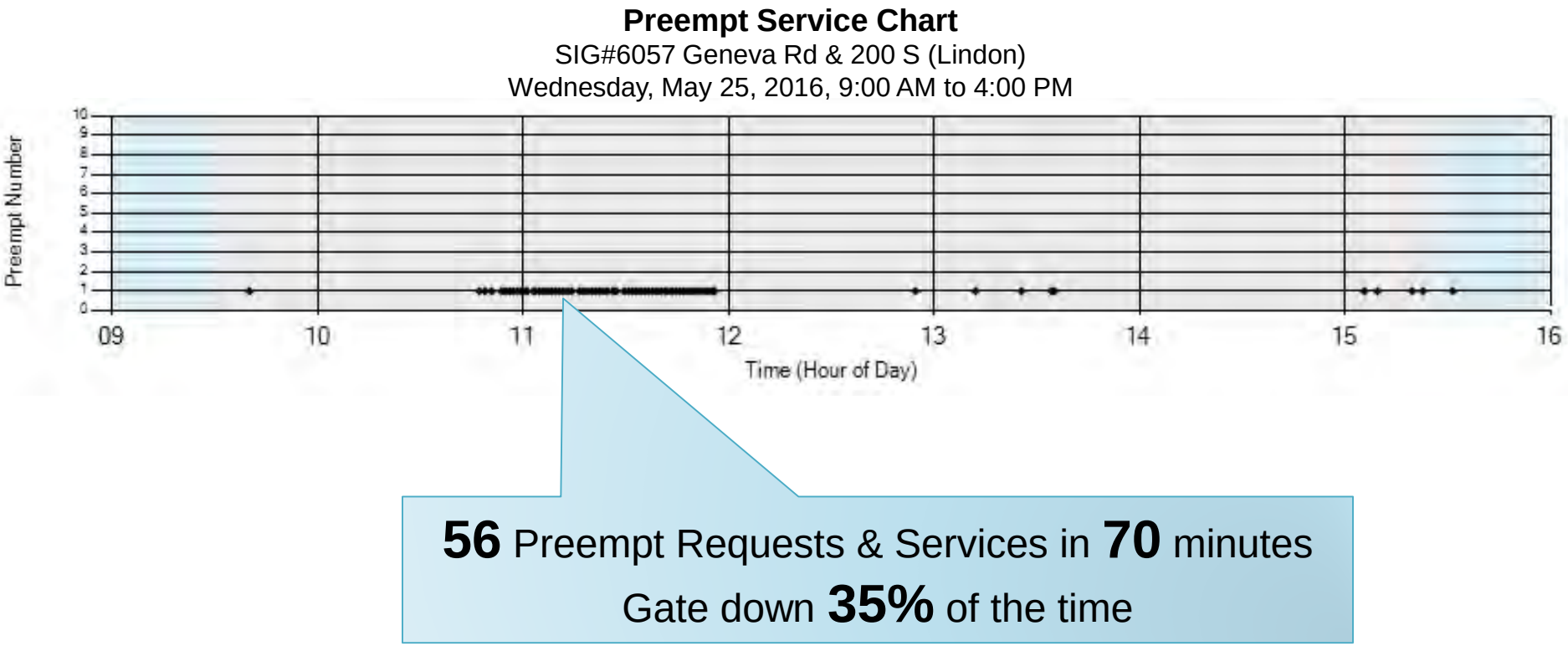


Railroad



Case Study: Preemption

Case Study: Preemption

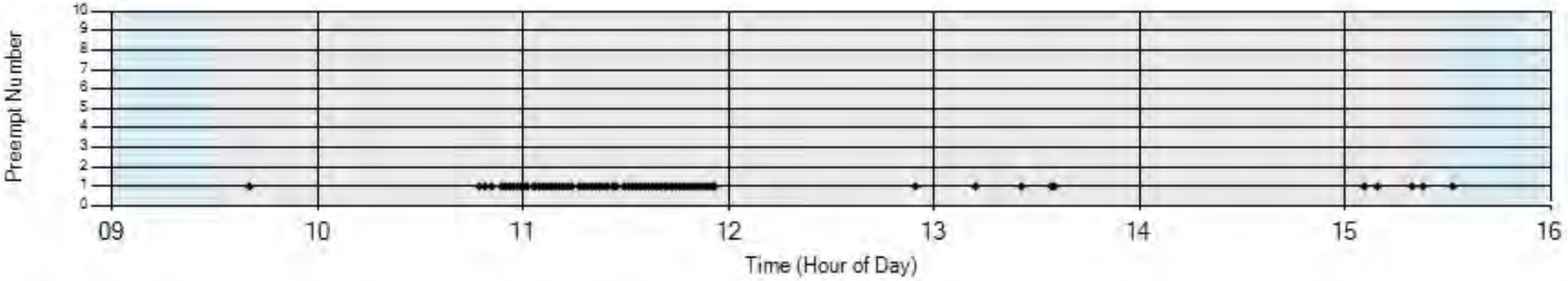


56 Preempt Requests & Services in **70** minutes

Gate down **35%** of the time

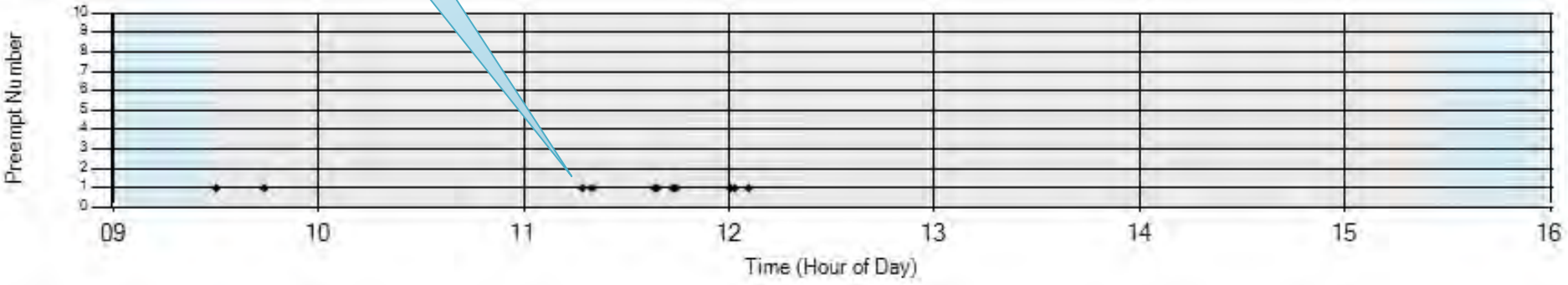
Case Study: Preemption

Preempt Service Chart
SIG#6057 Geneva Rd & 200 S (Lindon)
Wednesday, May 25, 2016, 9:00 AM to 4:00 PM



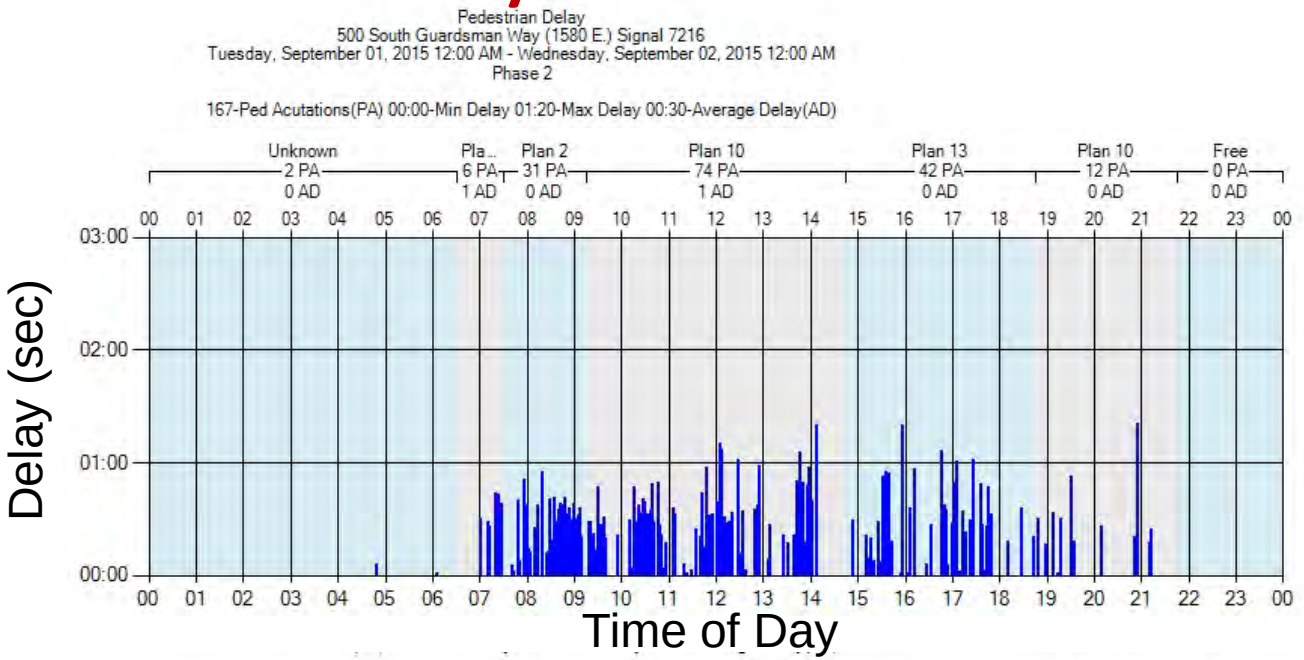
Fixed!

Preempt Service Chart
SIG#6057 Geneva Rd & 200 S (Lindon)
Wednesday, June 22, 2016, 9:00 AM to 4:00 PM

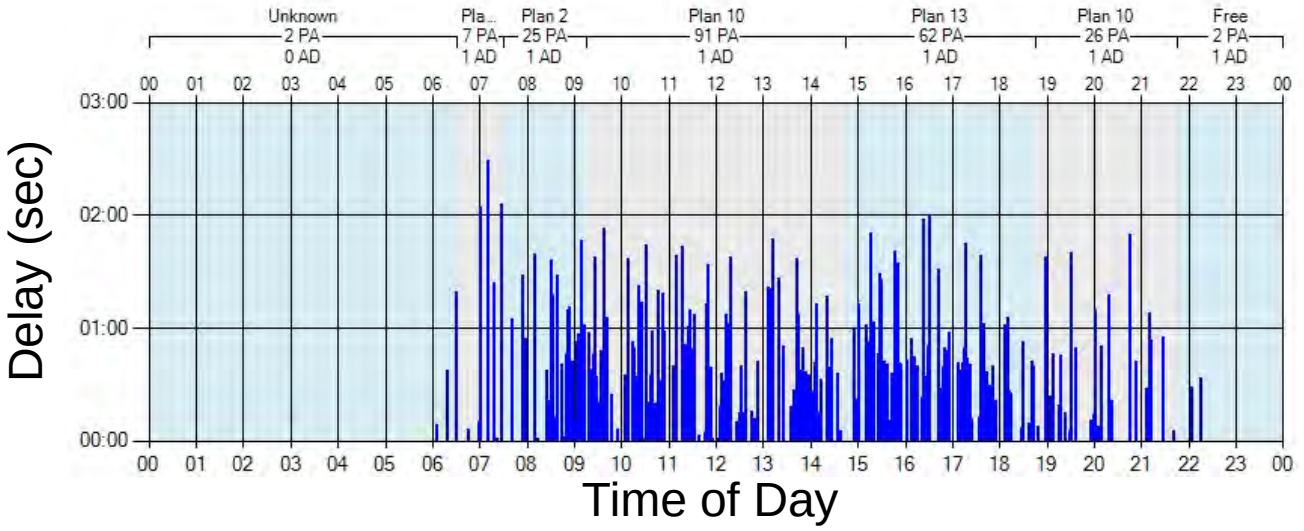


Metric: Pedestrian Delay

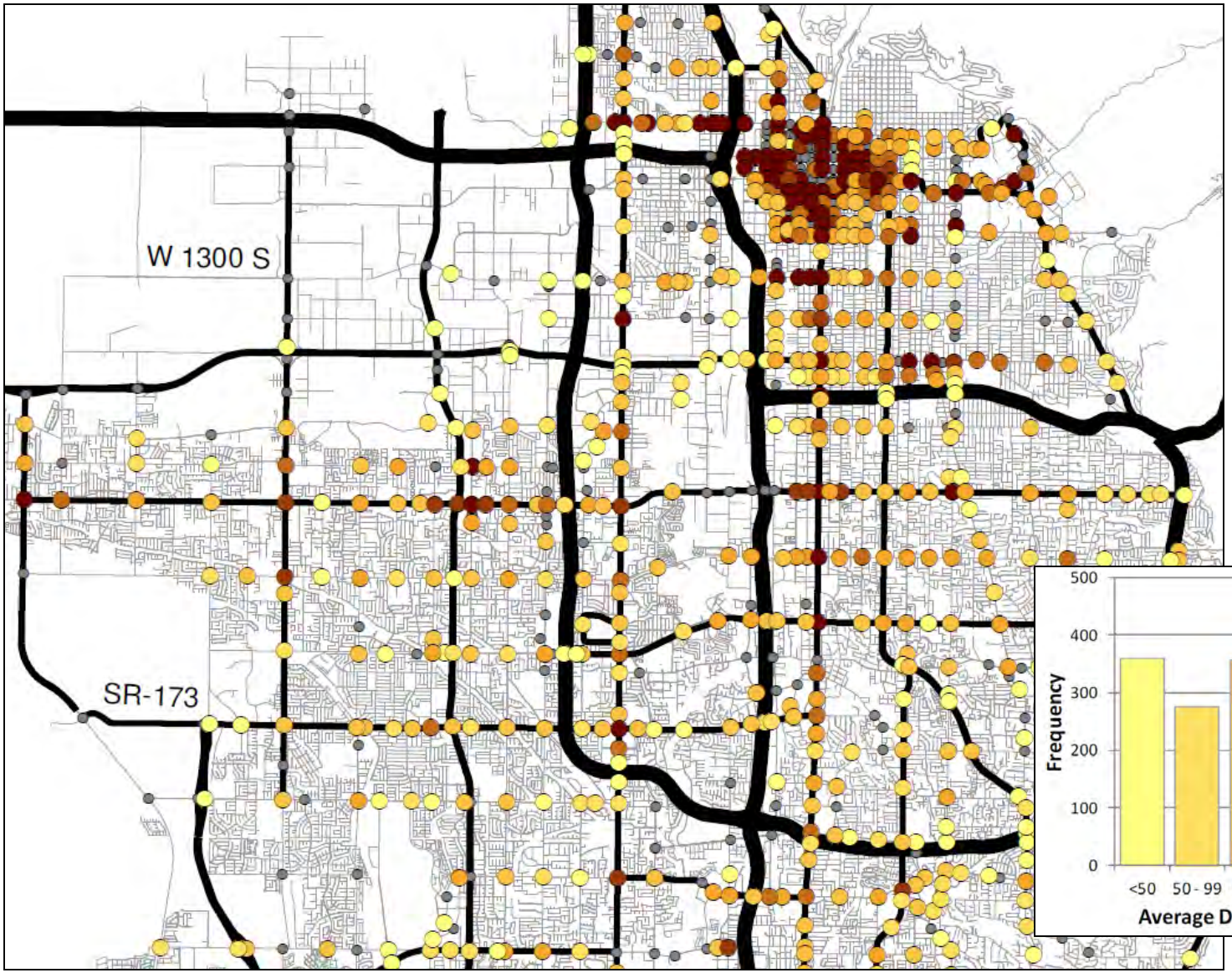
Phase 2
Coordinated phase



Phase 4
Side street

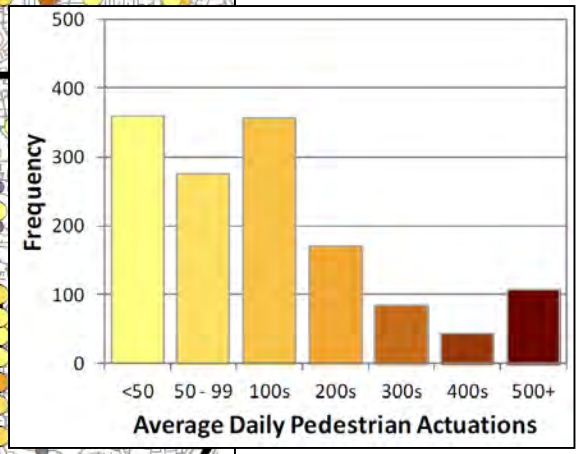


Active Transportation



Average Daily Pedestrian Actuations

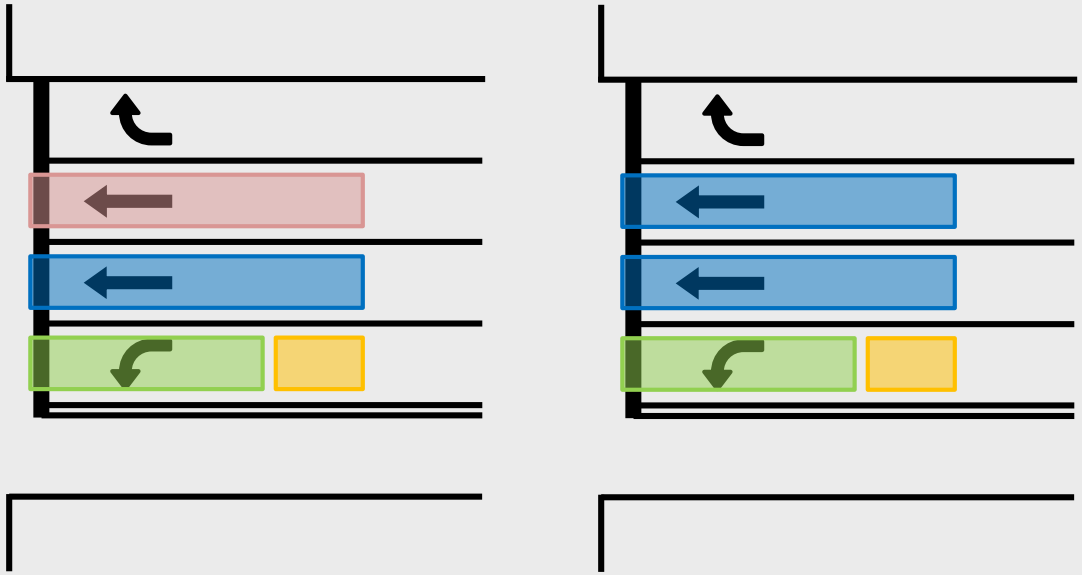
- <50
- 50 - 99
- 100 - 199
- 200 - 299
- 300 - 399
- 400 - 499
- 500+
- Unknown



Detection

Lane-by-lane Presence

Lane Group Presence



Available Metrics

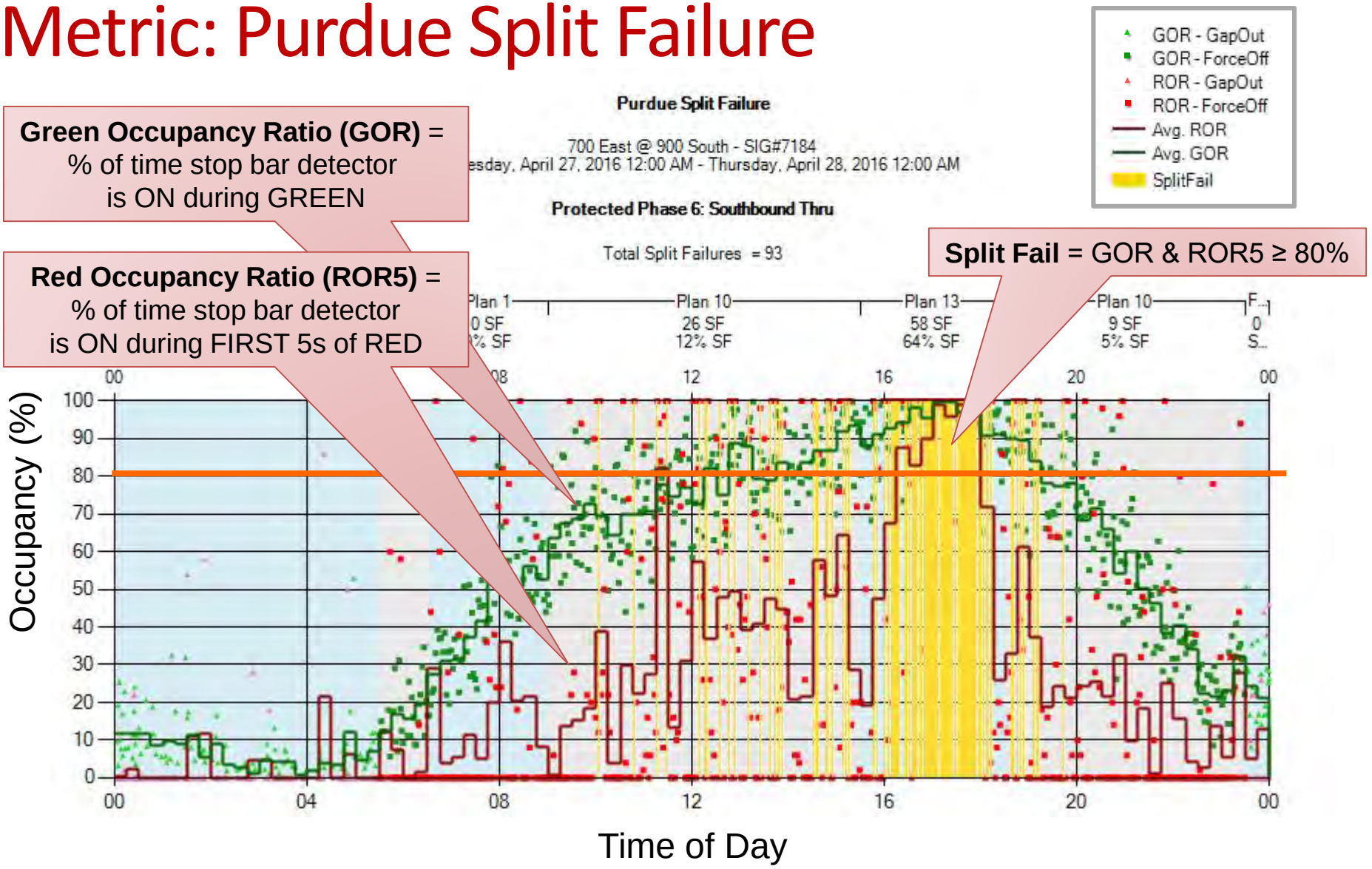
- Purdue Split Failure

Metric: Purdue Split Failure

Green Occupancy Ratio (GOR) = % of time stop bar detector is ON during GREEN

Red Occupancy Ratio (ROR5) = % of time stop bar detector is ON during FIRST 5s of RED

Split Fail = GOR & ROR5 ≥ 80%



Future Metric: Purdue Split Fail Ticker

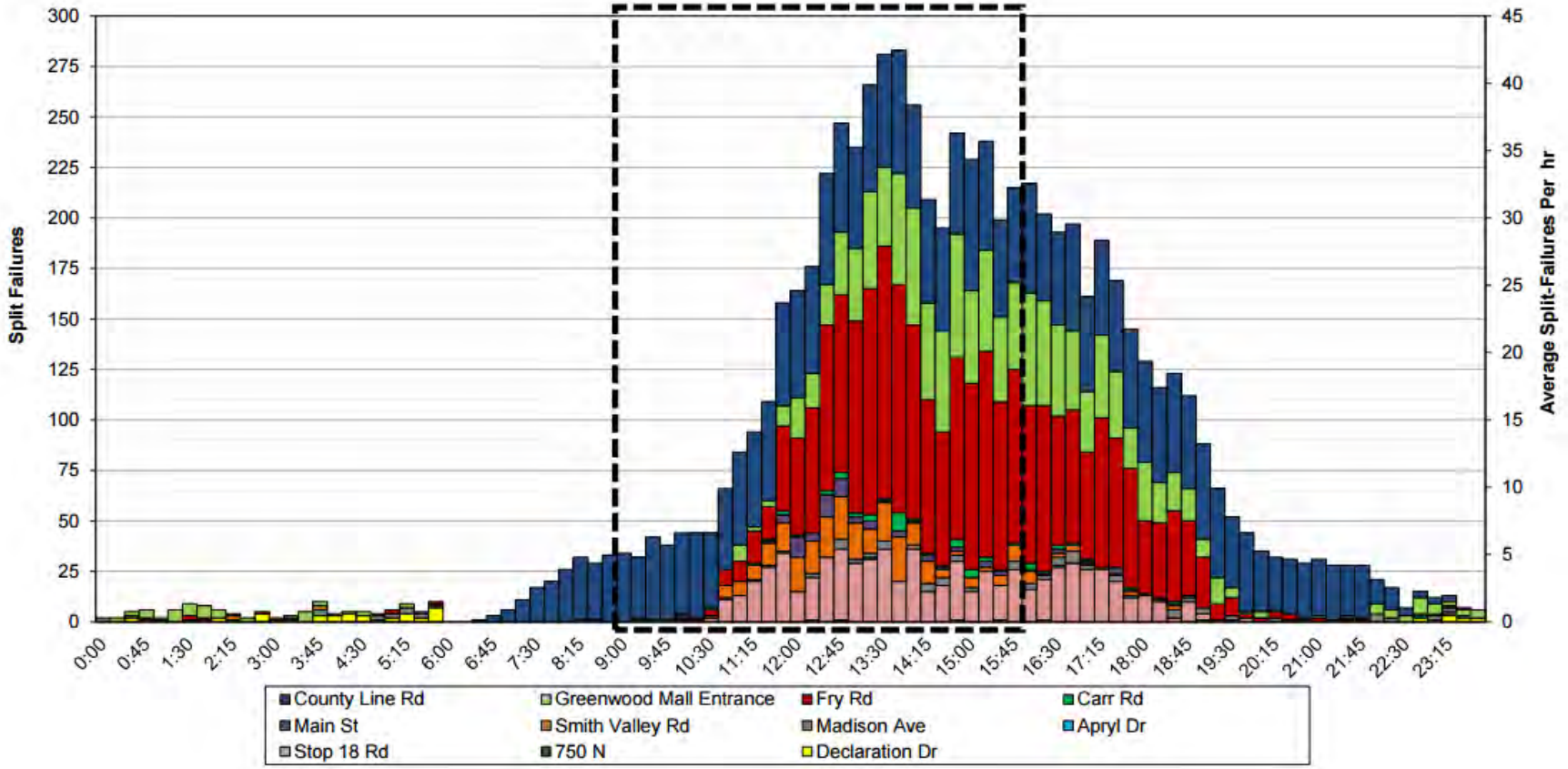
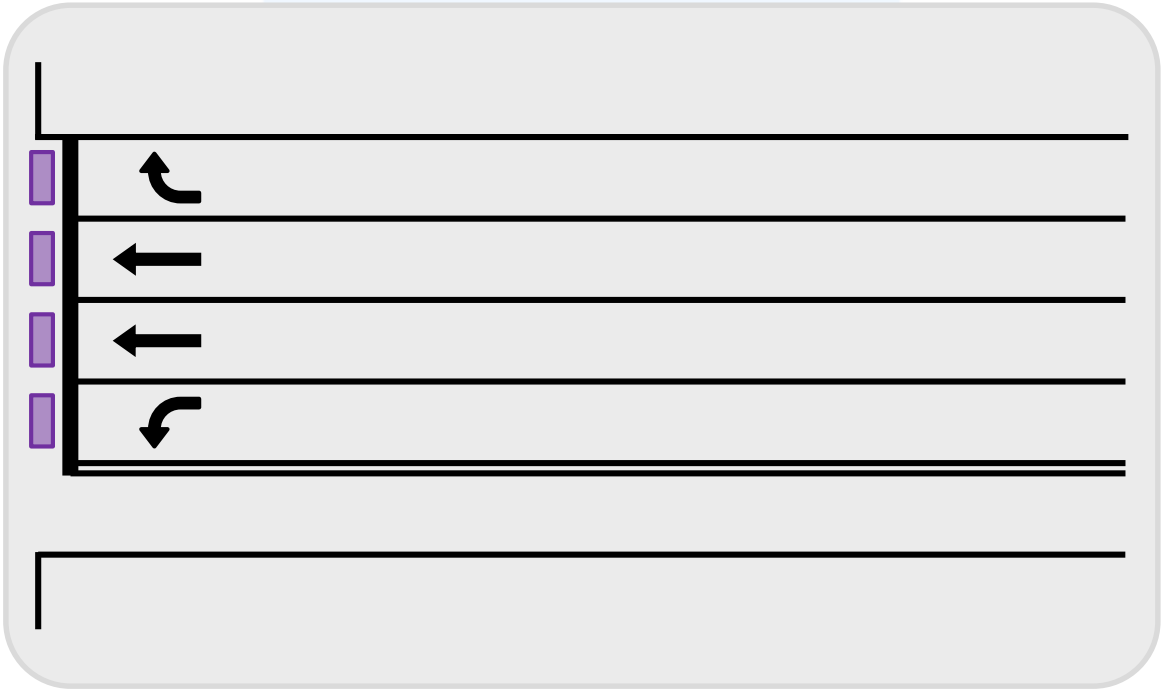


Figure 9. Aggregated split-failures over 24 hours on US-31 Greenwood for all Saturdays from January 1 to June 30, 2015.

Source: Scaling detailed high-resolution data split performance measures to statewide system level management (Paper No. 16-4149).

Detection

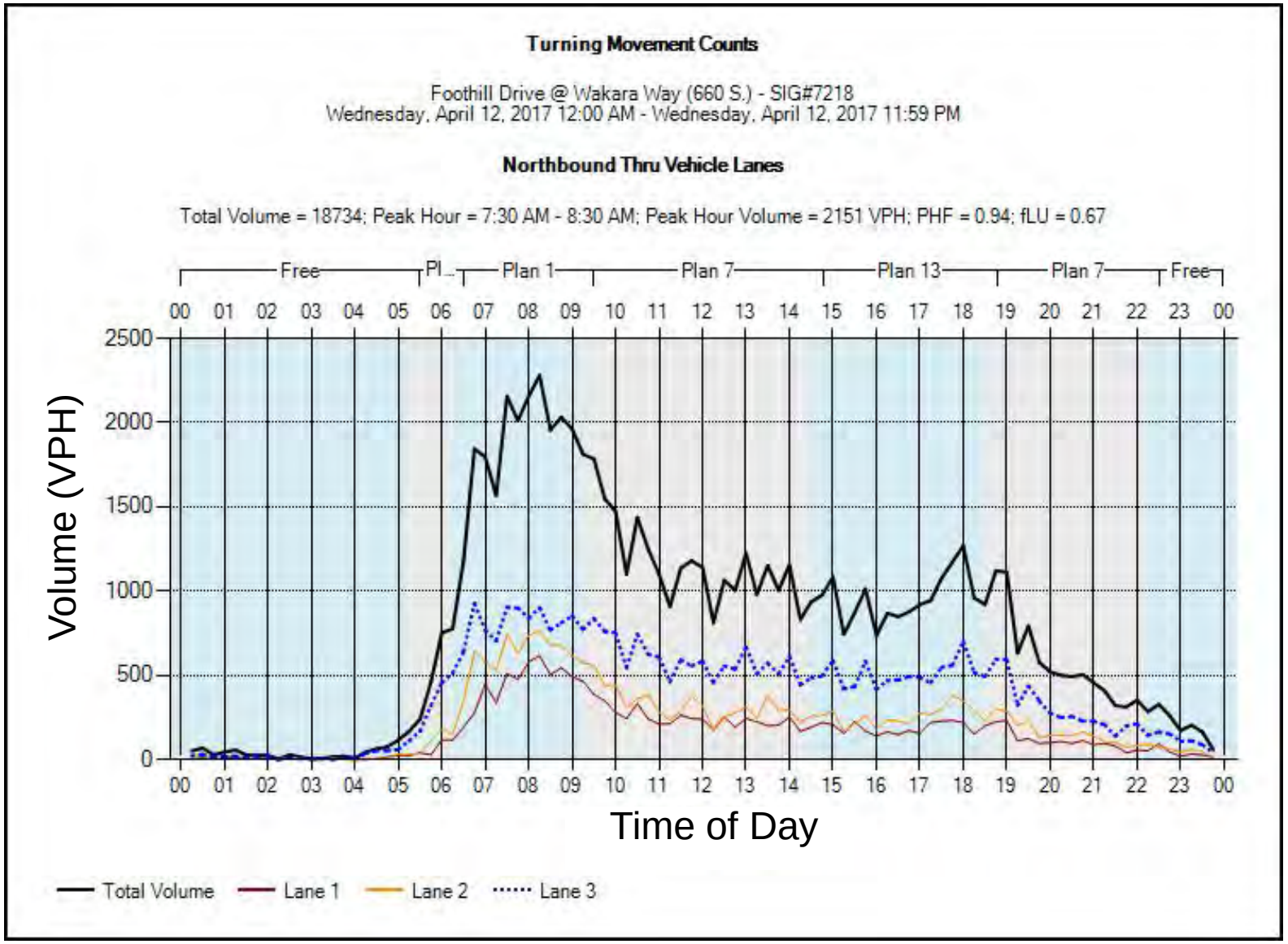
Lane-by-lane Count



Available Metrics

- Turning Movement Counts

Metric: Turning Movement Counts



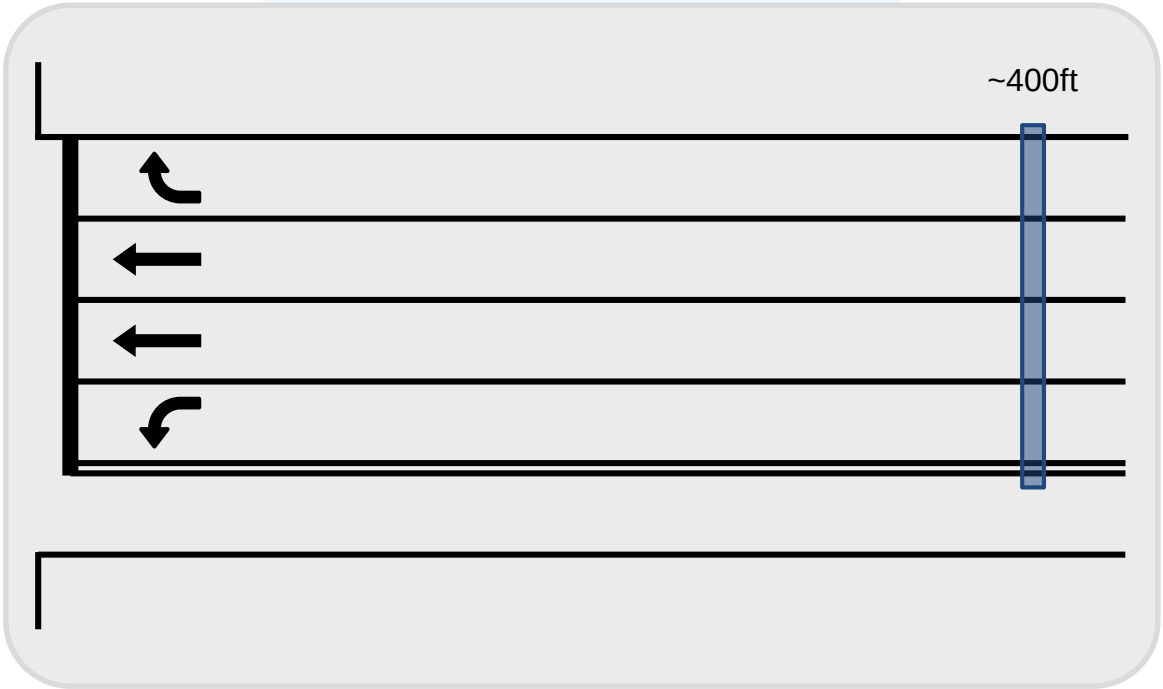
TMC Data Table

	Vehicle														
	Eastbound			Westbound			Northbound				Southbound				
	L	R	Total	L	R	Total	L	T	R	Total	L	T	R	Total	Vehicle Total
4:00 PM	18	29	47	202	181	383	2	217	50	269	51	468	9	528	1227
4:15 PM	7	35	42	188	186	374	4	212	40	256	59	415	4	478	1150
4:30 PM	13	37	50	206	165	371	9	219	36	264	67	479	6	552	1237
4:45 PM	10	20	30	202	188	390	7	230	36	273	64	483	7	554	1247
5:00 PM	7	17	24	214	192	406	4	236	42	282	53	423	4	480	1192
5:15 PM	5	19	24	187	163	350	5	269	44	318	46	478	10	534	1226
5:30 PM	7	21	28	163	149	312	7	293	40	340	49	415	9	473	1153
5:45 PM	9	11	20	122	124	246	5	317	45	367	51	382	4	437	1070
Total	76	189	265	1484	1348	2832	43	1993	333	2369	440	3543	53	4036	9502

	Peak Hour (PHF = 0.98)														
	Eastbound			Westbound			Northbound				Southbound				
	L	R	Total	L	R	Total	L	T	R	Total	L	T	R	Total	Vehicle Total
4:30 PM - 5:30 PM	35	93	128	809	708	1517	25	954	158	1137	230	1863	27	2120	4902

Detection

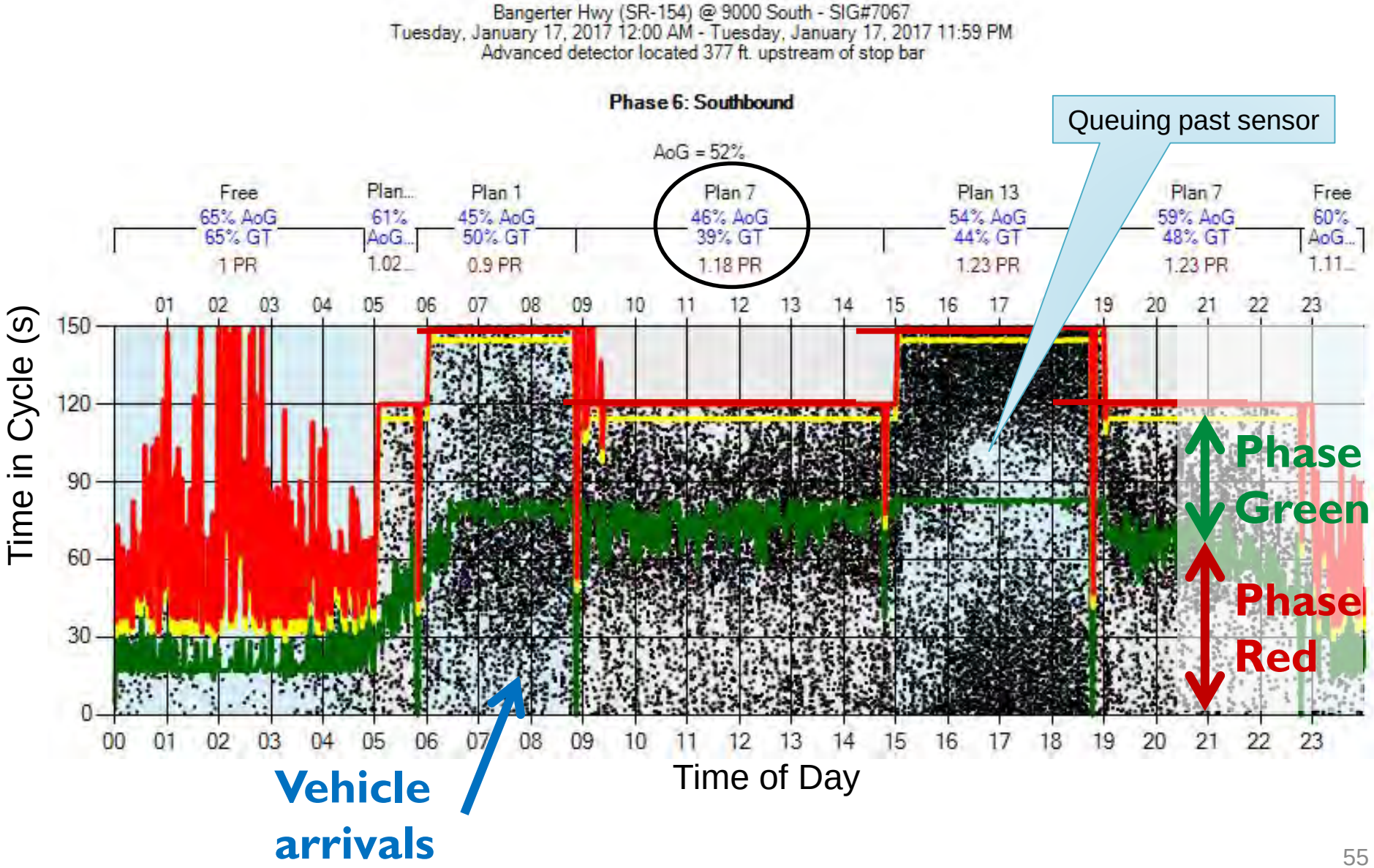
Setback Count Zones



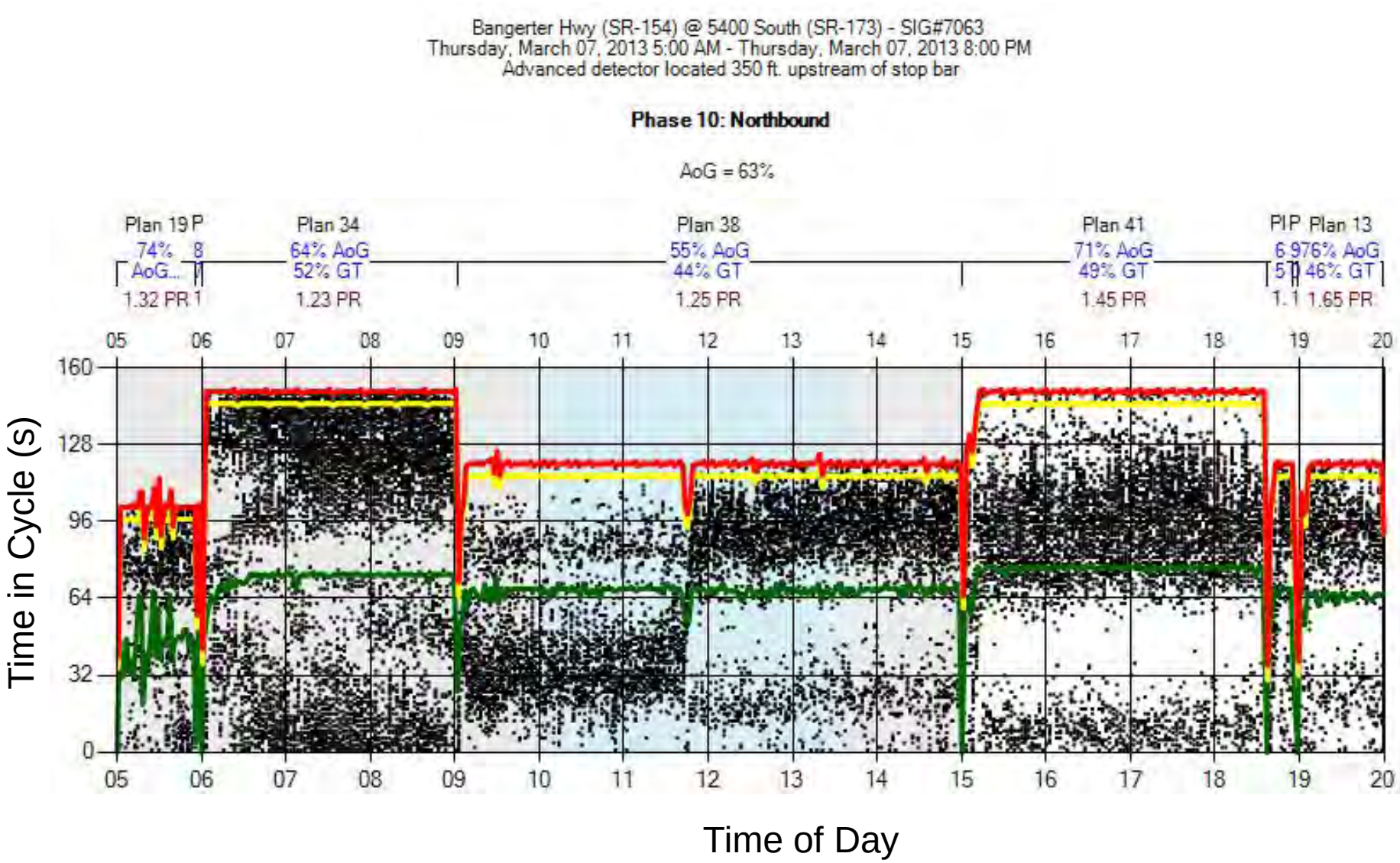
Available Metrics

- Purdue Coordination Diagram
- Approach Volume
- Arrivals on Red
- Approach Delay

Metric: Purdue Coordination Diagram



Purdue Coordination Diagram: Progression Quality



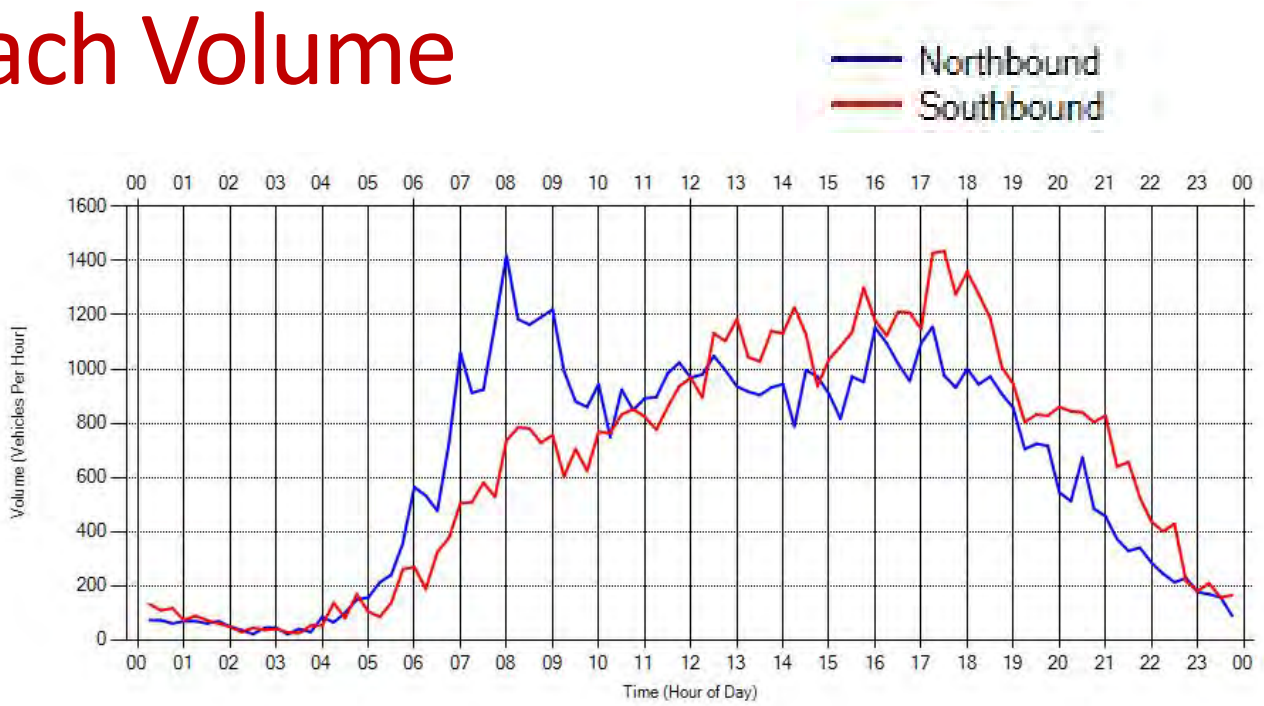
Metric: Approach Volume

Approach Volume

University Avenue @ East Bay Boulevard - SIG#6402
Wednesday, May 17, 2017 12:00 AM - Wednesday, May 17, 2017 11:59 PM

Northbound and Southbound Approaches

Wavetronix Matrix at stop bar

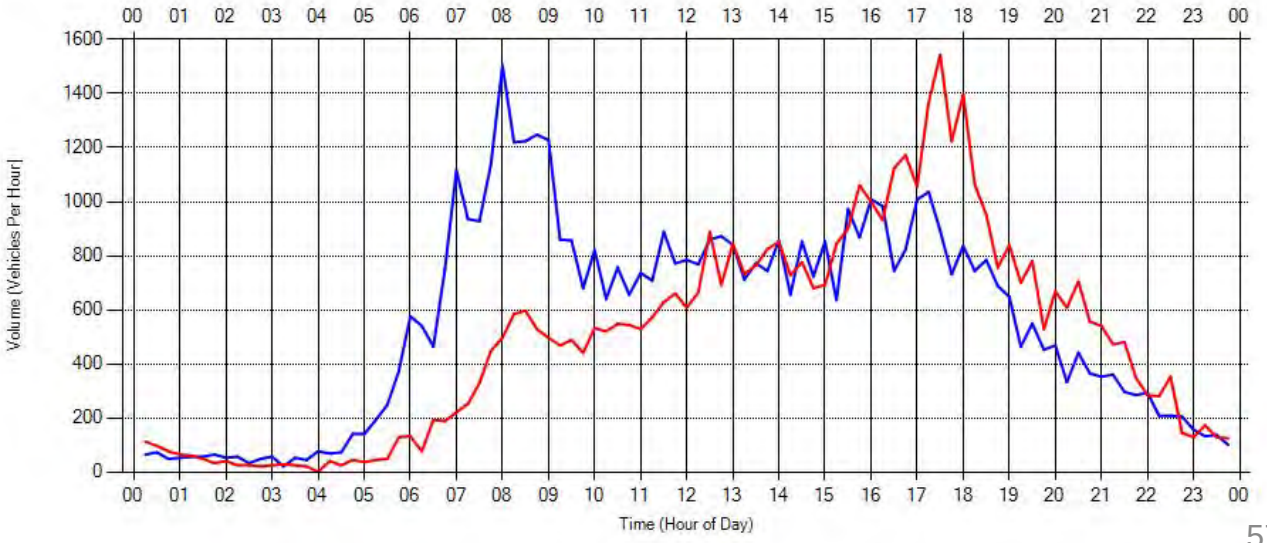


Approach Volume

University Avenue @ East Bay Boulevard - SIG#6402
Wednesday, May 17, 2017 12:00 AM - Wednesday, May 17, 2017 11:59 PM

Northbound and Southbound Approaches

Wavetronix Advance located 400ft. upstream of the stop bar



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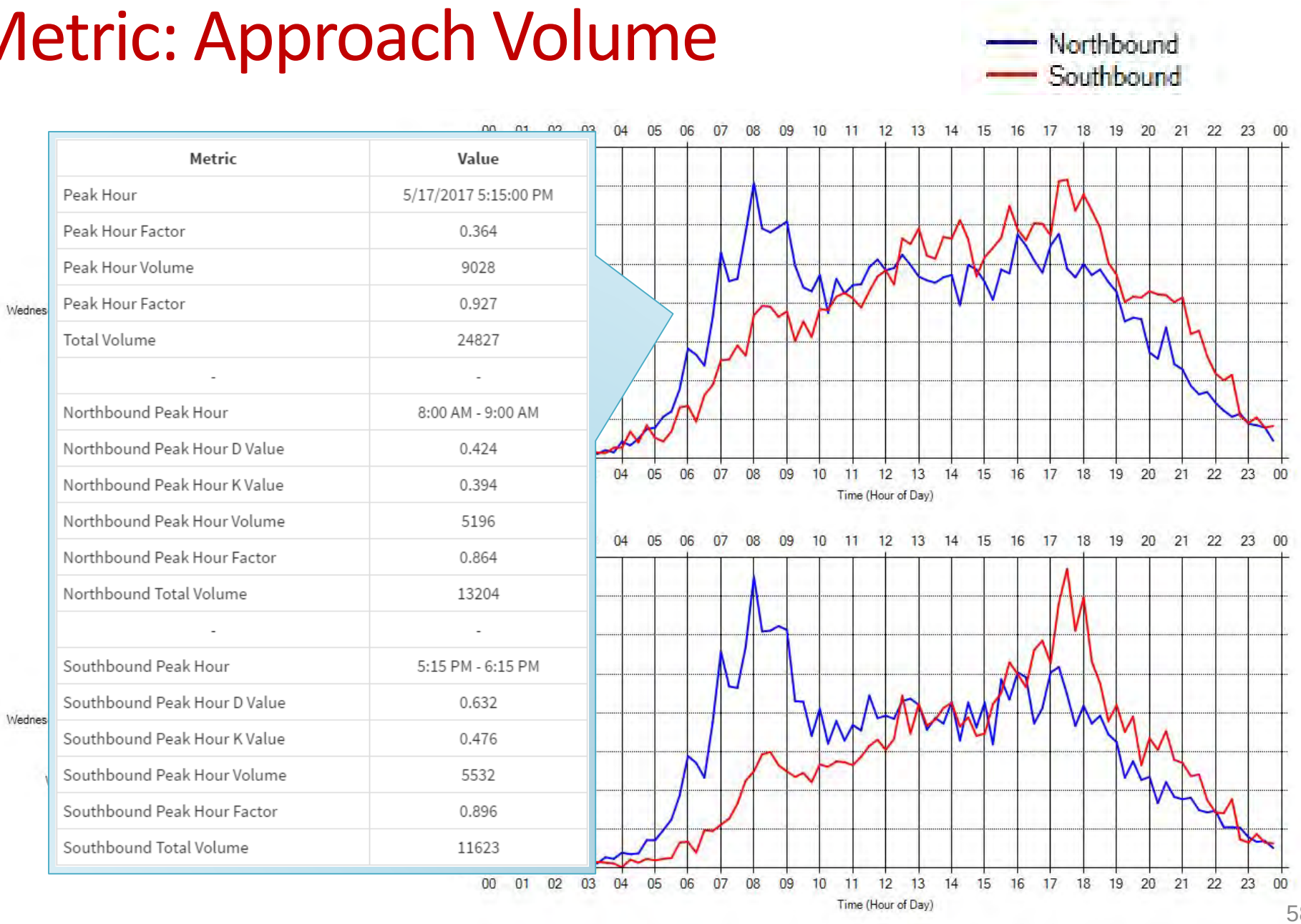
Metric: Approach Volume

Metric	Value
Peak Hour	5/17/2017 5:15:00 PM
Peak Hour Factor	0.364
Peak Hour Volume	9028
Peak Hour Factor	0.927
Total Volume	24827
-	-
Northbound Peak Hour	8:00 AM - 9:00 AM
Northbound Peak Hour D Value	0.424
Northbound Peak Hour K Value	0.394
Northbound Peak Hour Volume	5196
Northbound Peak Hour Factor	0.864
Northbound Total Volume	13204
-	-
Southbound Peak Hour	5:15 PM - 6:15 PM
Southbound Peak Hour D Value	0.632
Southbound Peak Hour K Value	0.476
Southbound Peak Hour Volume	5532
Southbound Peak Hour Factor	0.896
Southbound Total Volume	11623



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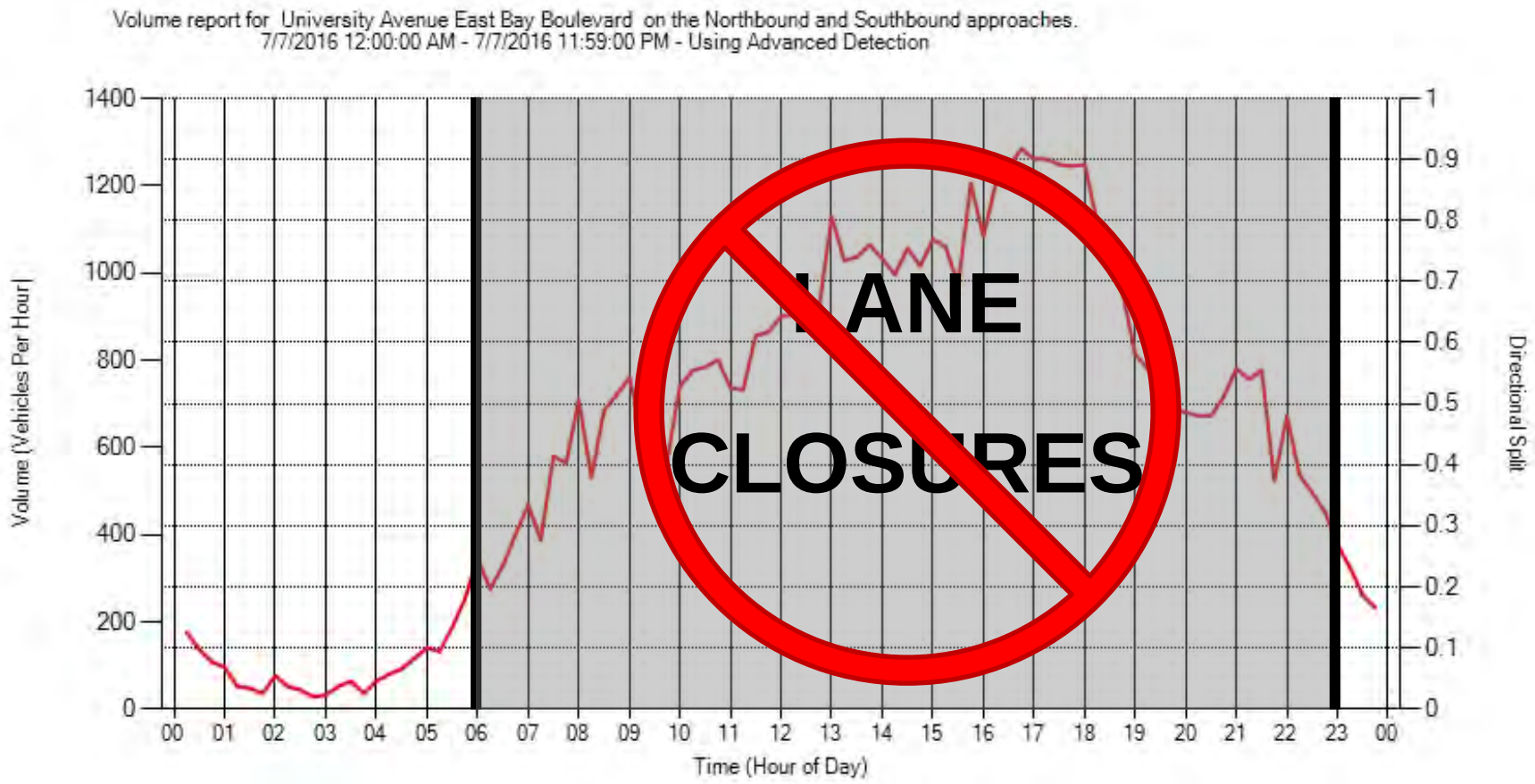
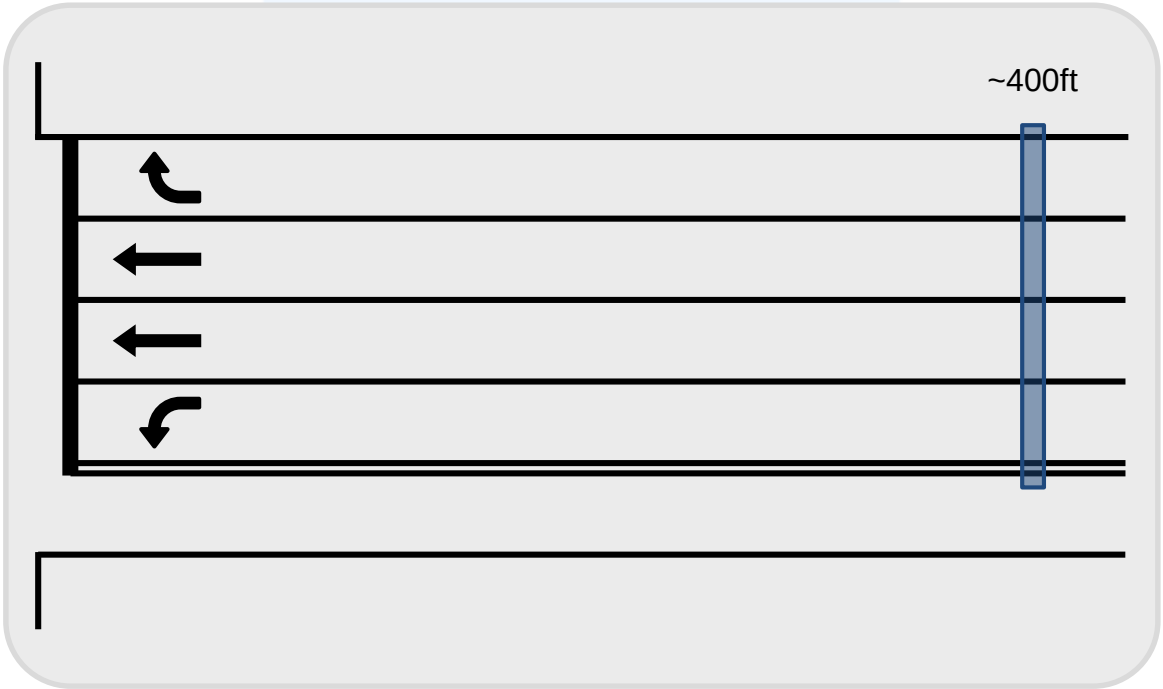
Allow Lane Closures



Detection

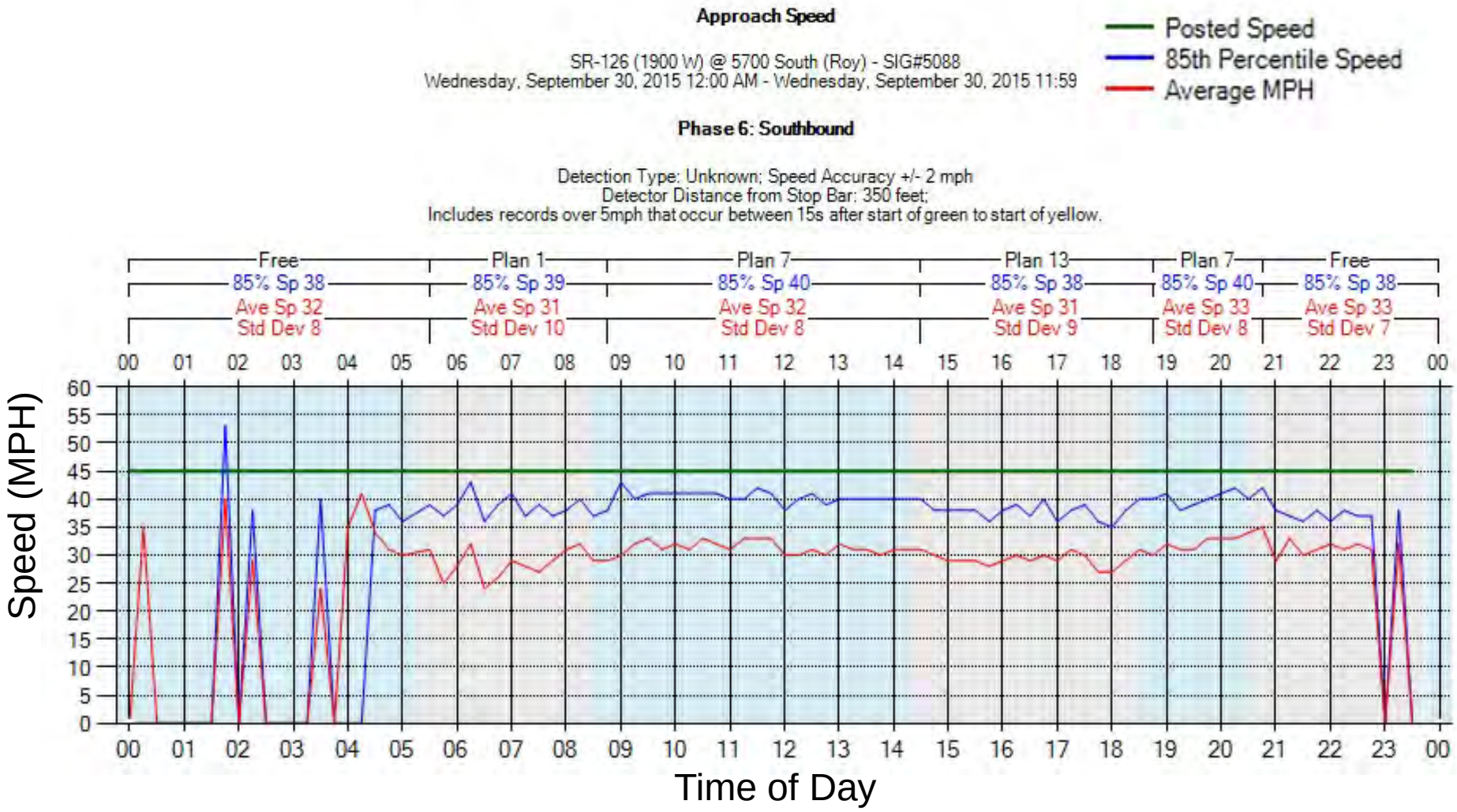
Setback Count Zones
with speed



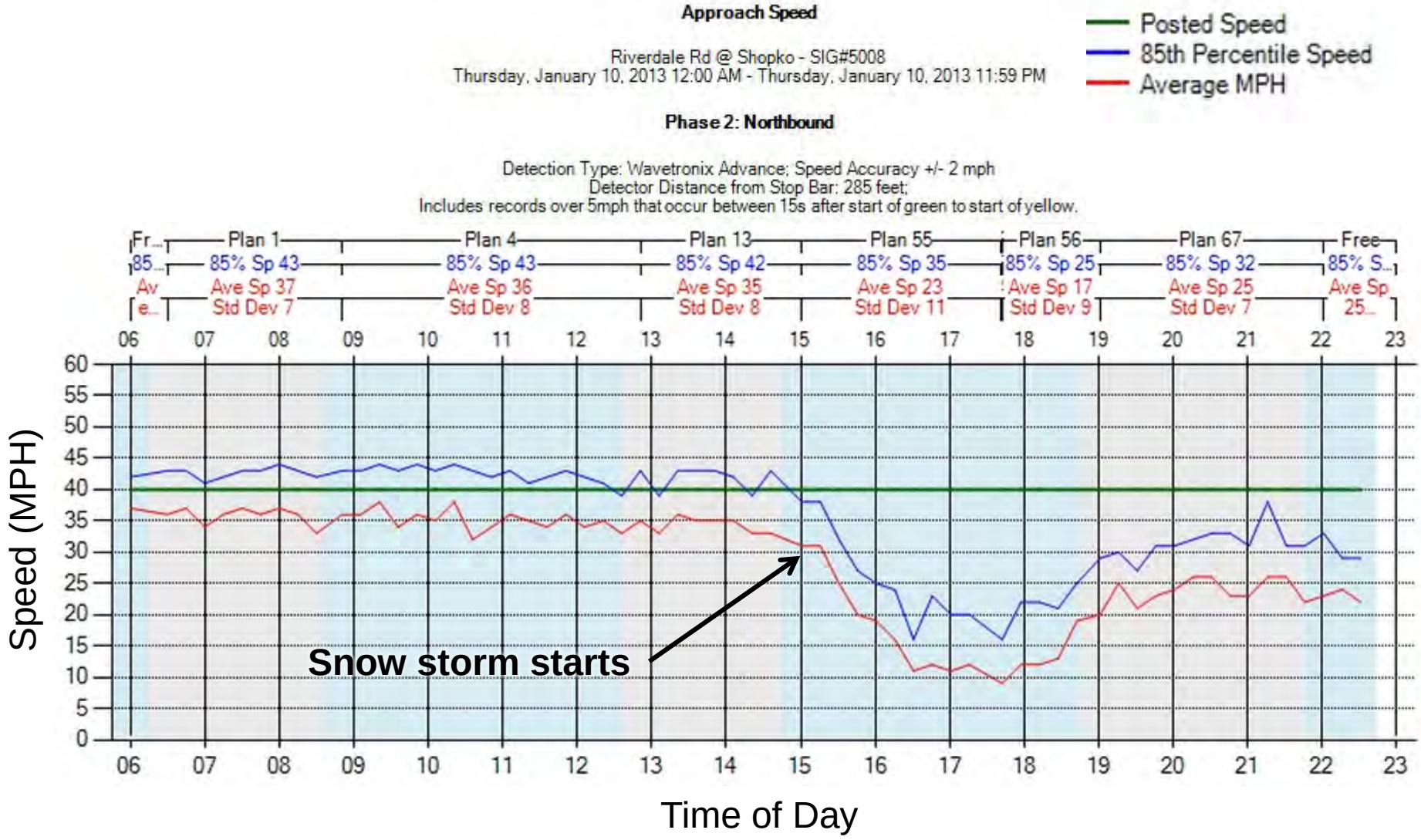
Available Metrics

- Approach Speed

Metric: Approach Speed



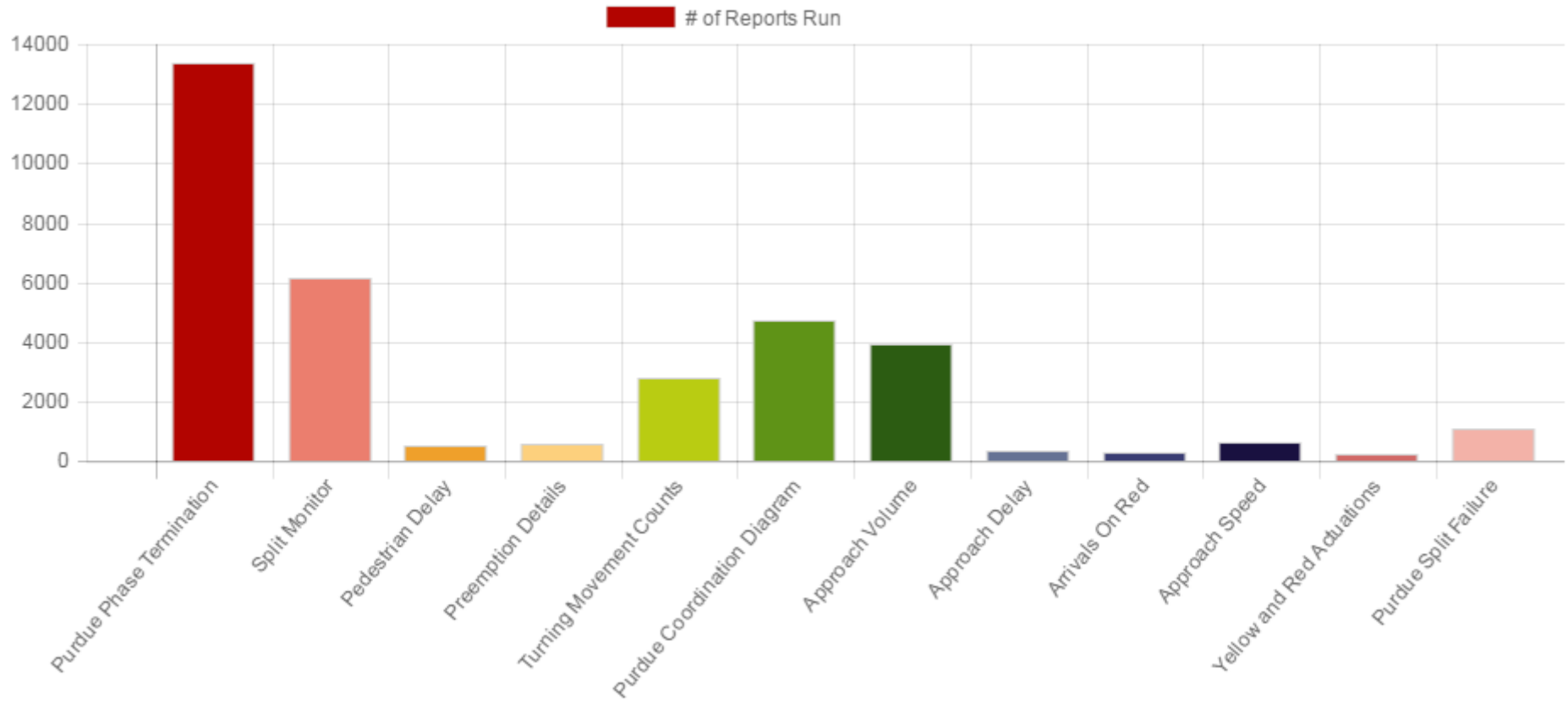
Metric: Approach Speed



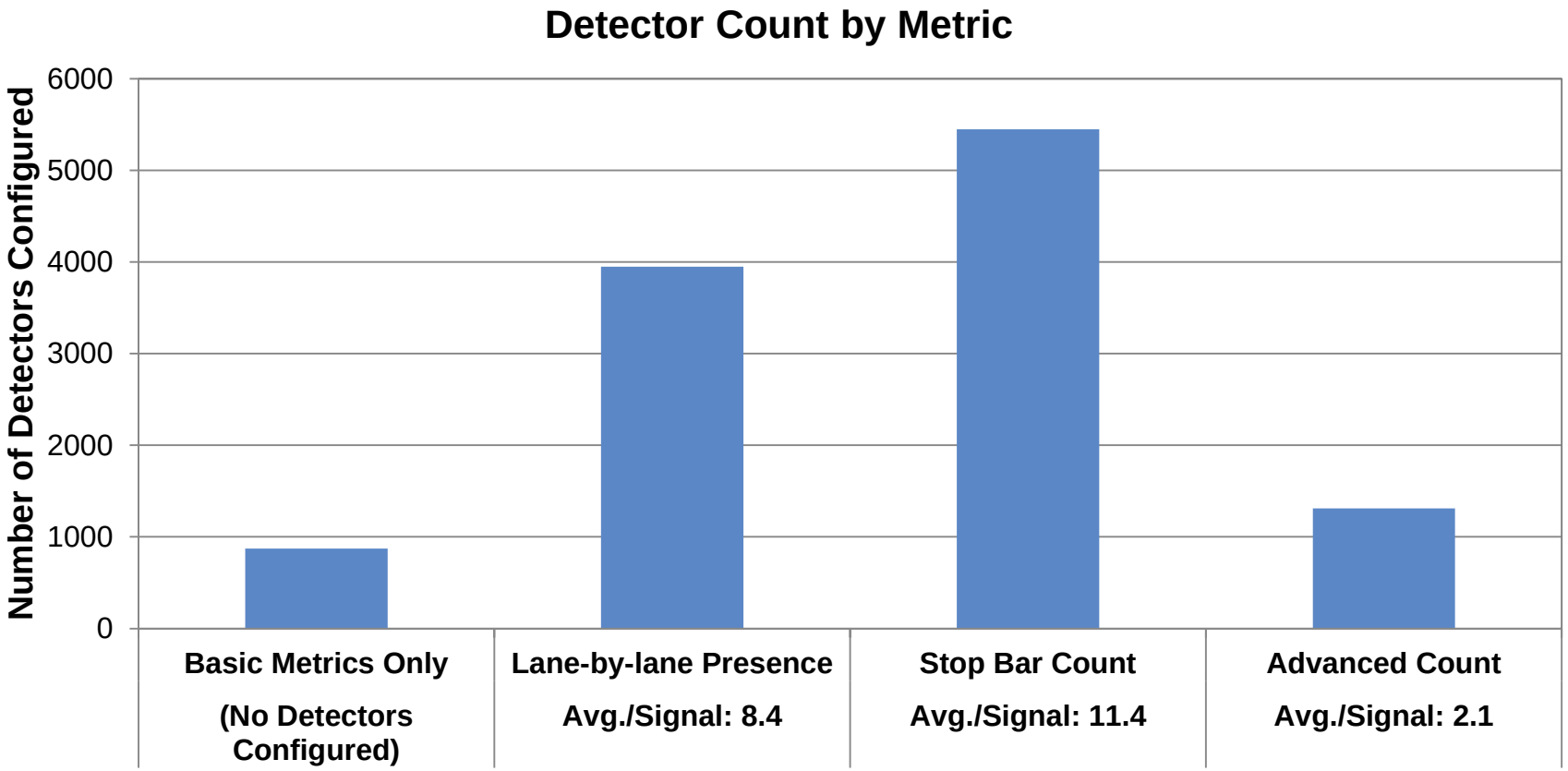
Metric Usage

Metrics Run
1/1/2017 – 5/21/2017

Collected by automatic logger



UDOT ATSPM Configuration Records

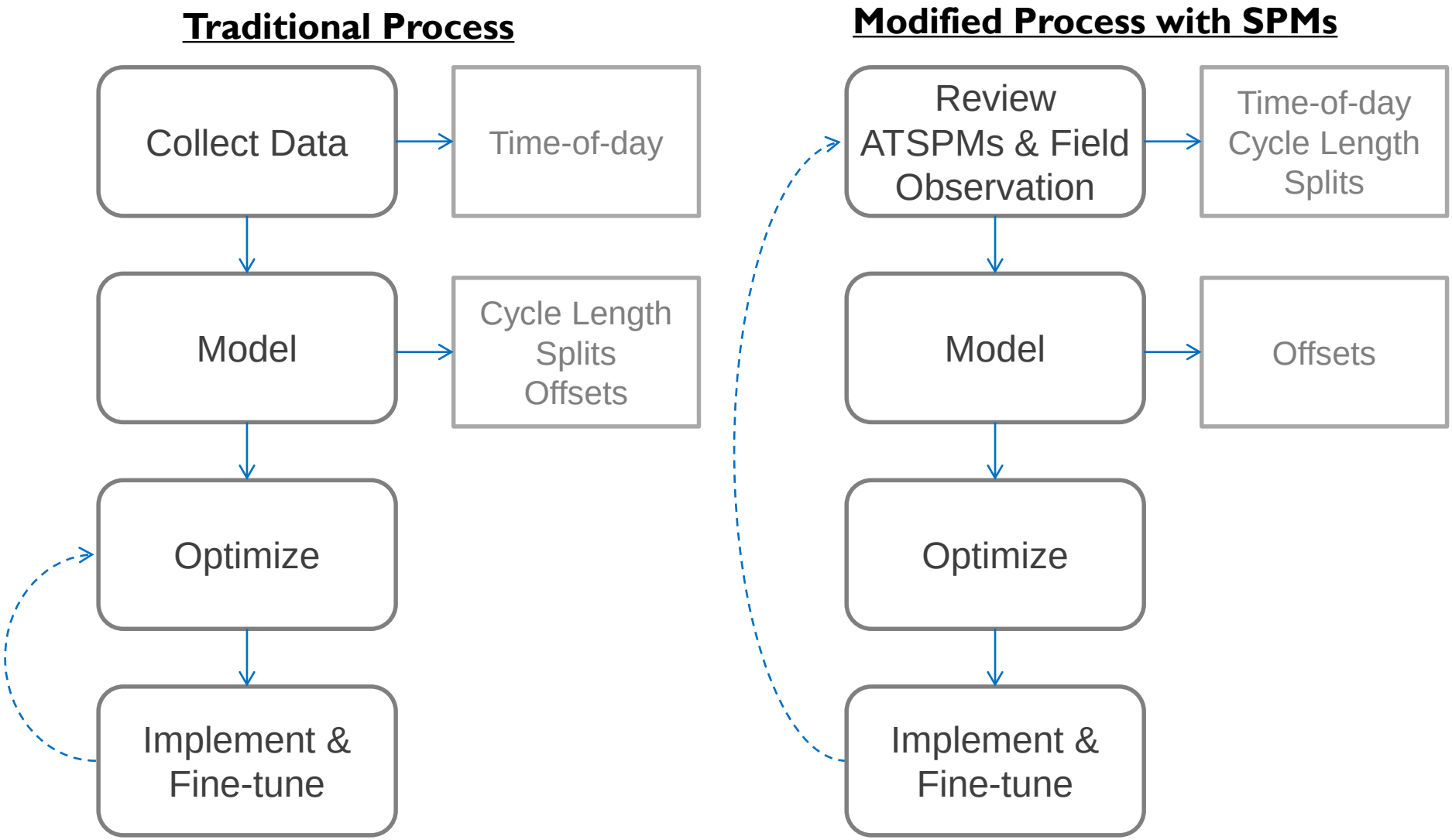


Total: 10,700 detectors + 1785 signals

SIGNAL OPTIMIZATION

UDOT Automated Traffic Signal Performance Measures

Optimization with ATSPMs



Evaluate Impact of Timing Change

- Before:

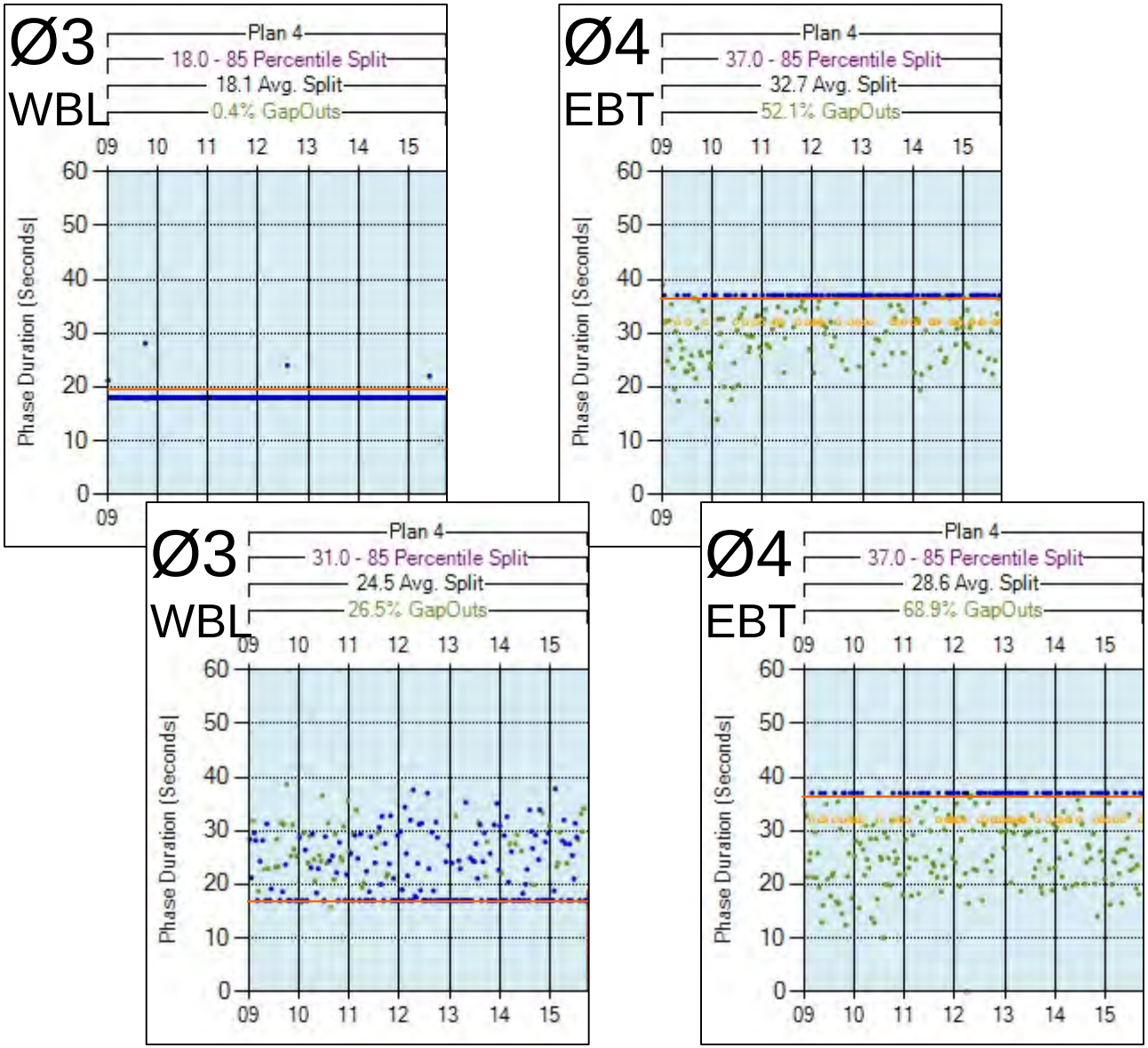
1 2 | 3 4

5 6 | 7 8

- After:

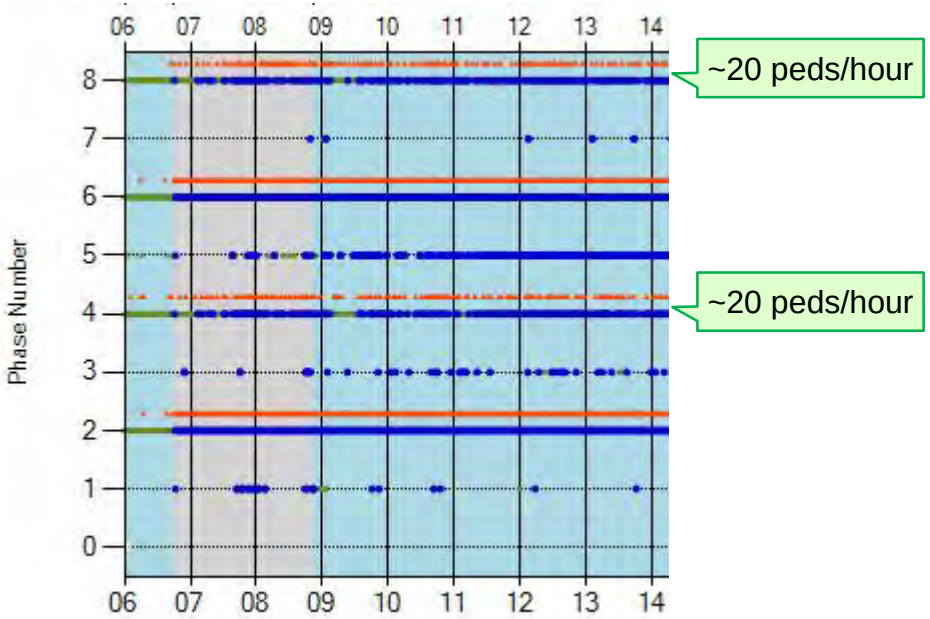
1 2 | 4 3

5 6 | 7 8

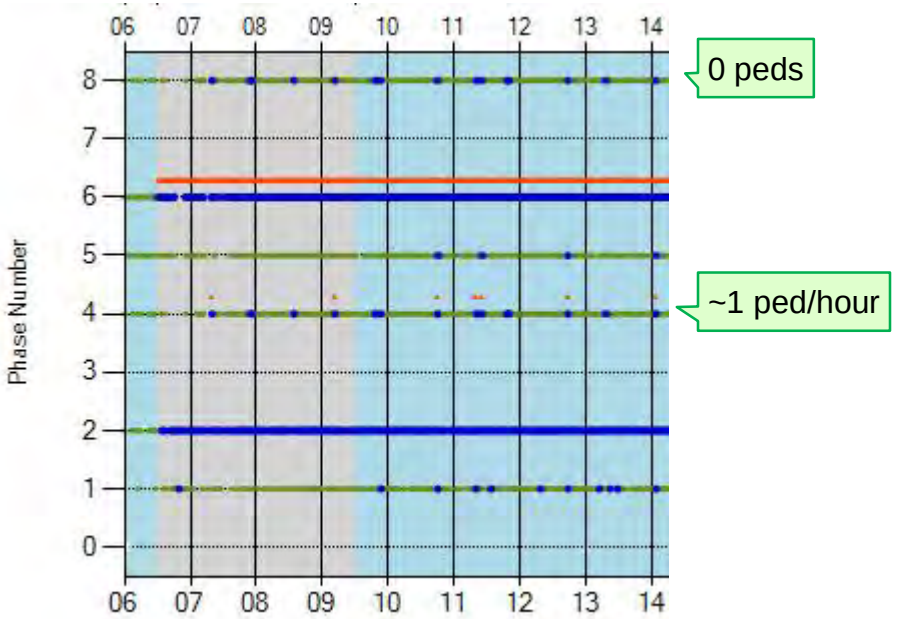


"Can we oversize the peds?"

Peds for Phases 4 & 8 are called **frequently**
Recommendation: Do not oversize peds



Peds for Phases 4 & 8 are **rarely** called
Recommendation: Oversize peds, if needed



- Gap out
- Max out
- Force off
- Pedestrian activation (shown above phase line)
- Skip

SYSTEM HEALTH ALERTS

UDOT Automated Traffic Signal Performance Measures

System Health Alerts

1. **No SPM data:** identifies signals with less than 500 records in the database between midnight and midnight the previous day
2. **Too many max outs:** identifies phases with more than 90% max outs in at least 50 activations between 1 a.m. and 5 a.m.
3. **Too many force offs:** identifies phases with more than 90% force offs in at least 50 activations between 1 a.m. and 5 a.m.
4. **Too many ped calls:** identifies phases with more than 200 pedestrian activations between 1 a.m. and 5 a.m.
5. **Low PCD detector count:** identifies phases with PCD detectors that have less than 100 vehicles counted between 5 p.m. and 6 p.m. the previous day.

SPM Alerts for 5/22/2016

SPMWatchdog@utah.gov
to marktaylor, me, signaldesk, shanejohnson, bryan.meenen, kbarnes, SWinters, tforbush, jay

--The following signals had too few records in the database:
4671 - 13400 South & 4500 West - Phase: 0 (Missing Records)
5701 - 500 South & 400 East (Btfl) - Phase: 0 (Missing Records)

--The following signals had too many force off occurrences:
1224 - North Temple & Main Street - Phase: 3 (Force Offs 97.6%)
7252 - 500 South & Main Street - Phase: 2 (Force Offs 100%)
7252 - 500 South & Main Street - Phase: 6 (Force Offs 100%)

--The following signals had too many max out occurrences:
1123 - Wolcott St & 100 South - Phase: 2 (Max Outs 100%)
1124 - Sunnyside (850 S) & Gaurdsman Way - Phase: 2 (Max Outs 100%)
1124 - Sunnyside (850 S) & Gaurdsman Way - Phase: 6 (Max Outs 100%)
4024 - 7000 South (Fort Union) & 1300 East - Phase: 7 (Max Outs 92.6%)
4029 - 7200 South & 700 East - Phase: 1 (Max Outs 100%)
4103 - 4680 South (Murray-Holladay) & 2320 East (Holladay) - Phase: 5 (Max Outs 100%)
4118 - 6200 South & 3655 West (Dixie) - Phase: 2 (Max Outs 100%)
4511 - 4100 South & 3200 West - Phase: 4 (Max Outs 100%)
4820 - 4835 South & 2700 West - Phase: 2 (Max Outs 100%)
5063 - Lincoln & 24th - Phase: 4 (Max Outs 100%)
5063 - Lincoln & 24th - Phase: 8 (Max Outs 100%)
5080 - Washington & Adams - Phase: 5 (Max Outs 100%)
5170 - 200 N (Kaysville) & Main St. - Phase: 4 (Max Outs 100%)
5305 - Main St. & 200 North (Logan) - Phase: 7 (Max Outs 96.2%)
5900 - 900 W. (Kays Dr.) & 200 North, (Kaysville) - Phase: 4 (Max Outs 90.4%)
6035 - Pioneer Crossing & Millpond Drive - Phase: 8 (Max Outs 91.9%)
6608 - 100 West & 100 North - Phase: 8 (Max Outs 98.5%)
7107 - Redwood Road & 4700 South - Phase: 5 (Max Outs 93.2%)

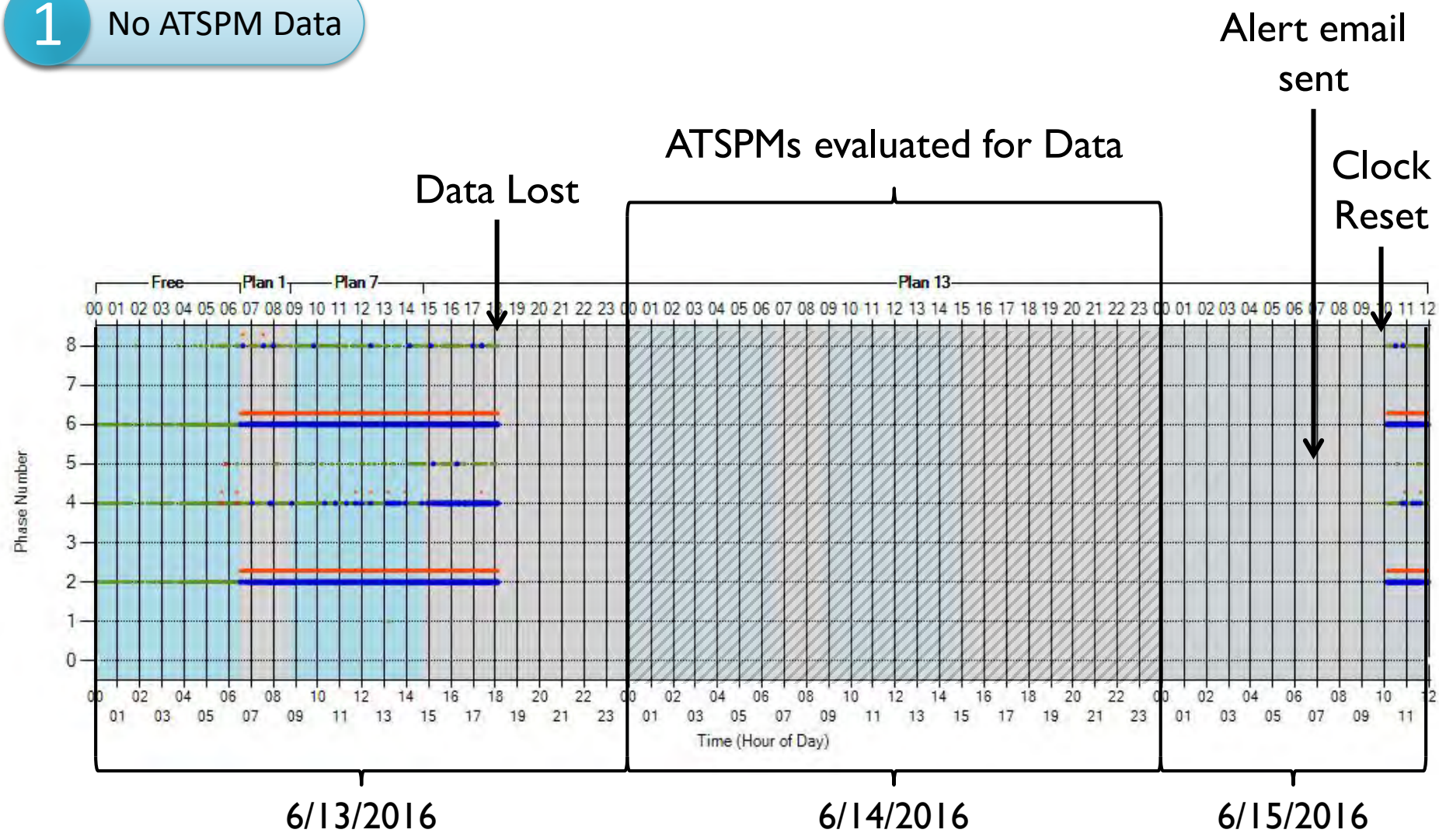
--The following signals had unusually low detector hits:
5134 - SR-193 (700 S) & I-15 NB (Clearfield) - Phase: 2 (Has Unusually Low Counts.)
7061 - Bangerter Hwy (SR-154) & 4100 South - Phase: 1 (Has Unusually Low Counts.)
7061 - Bangerter Hwy (SR-154) & 4100 South - Phase: 7 (Has Unusually Low Counts.)
7361 - Bangerter Hwy (SR-154) & 13400 South - Phase: 1 (Has Unusually Low Counts.)

--The following signals have stuck ped detectors:
1023 - South Temple & 200 West - Phase: 2 (Stuck Ped)
1023 - South Temple & 200 West - Phase: 4 (Stuck Ped)
1023 - South Temple & 200 West - Phase: 6 (Stuck Ped)
1023 - South Temple & 200 West - Phase: 8 (Stuck Ped)
4511 - 4100 South & 3200 West - Phase: 4 (Stuck Ped)
6009 - Main (Lehi) & I-15 SPUI - Phase: 6 (Stuck Ped)
7826 - 9800 S (Little Cottonwood Rd) & Wasatch Blvd (3500 E) - Phase: 4 (Stuck Ped)

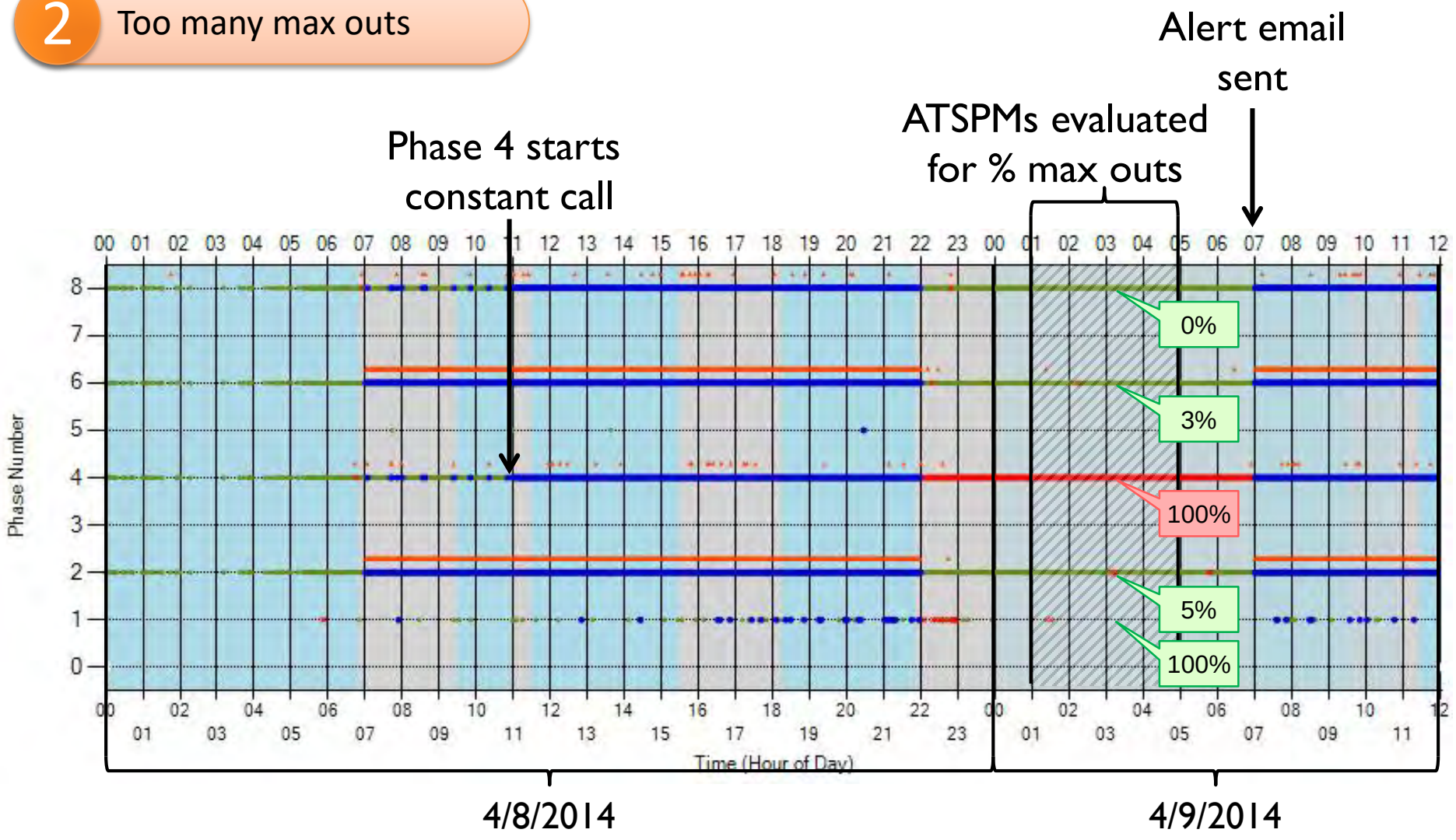
Alert Evaluation

1 No ATSPM data	Check communication to signal
	Check controller clock
	Check IP address in SPM configuration
	Check VIOT = NO & DB State = All Saved (Econolite MM 9-3-1 SpFn*3)
	Try enabling Upload Current
	Create a WO to cold start the controller
2 Too many max outs	Check for recalls
	Check for constant call on a detector channel
	Consider whether a bandaid is necessary
3 Too many force offs	Should the signal be in coordination?
	Is a non-coordinated phase maxing out?
	Skip only 2-6 pairs and dummy phases
4 Too many ped calls	Check for recalls
	Check for constant call on a detector channel
5 Low PCD detector count	*Note: Evaluate the VOLUME on the PCD charts, not the phase data*
	Is count channel configured correctly in SPM Config Tool?
	Is ECPI Log enabled for count channel?
	Is the detector working?
	Is the detector communicating to the controller?
	Try resetting the sensor and VERIFY with Upload Current

1 No ATSPM Data

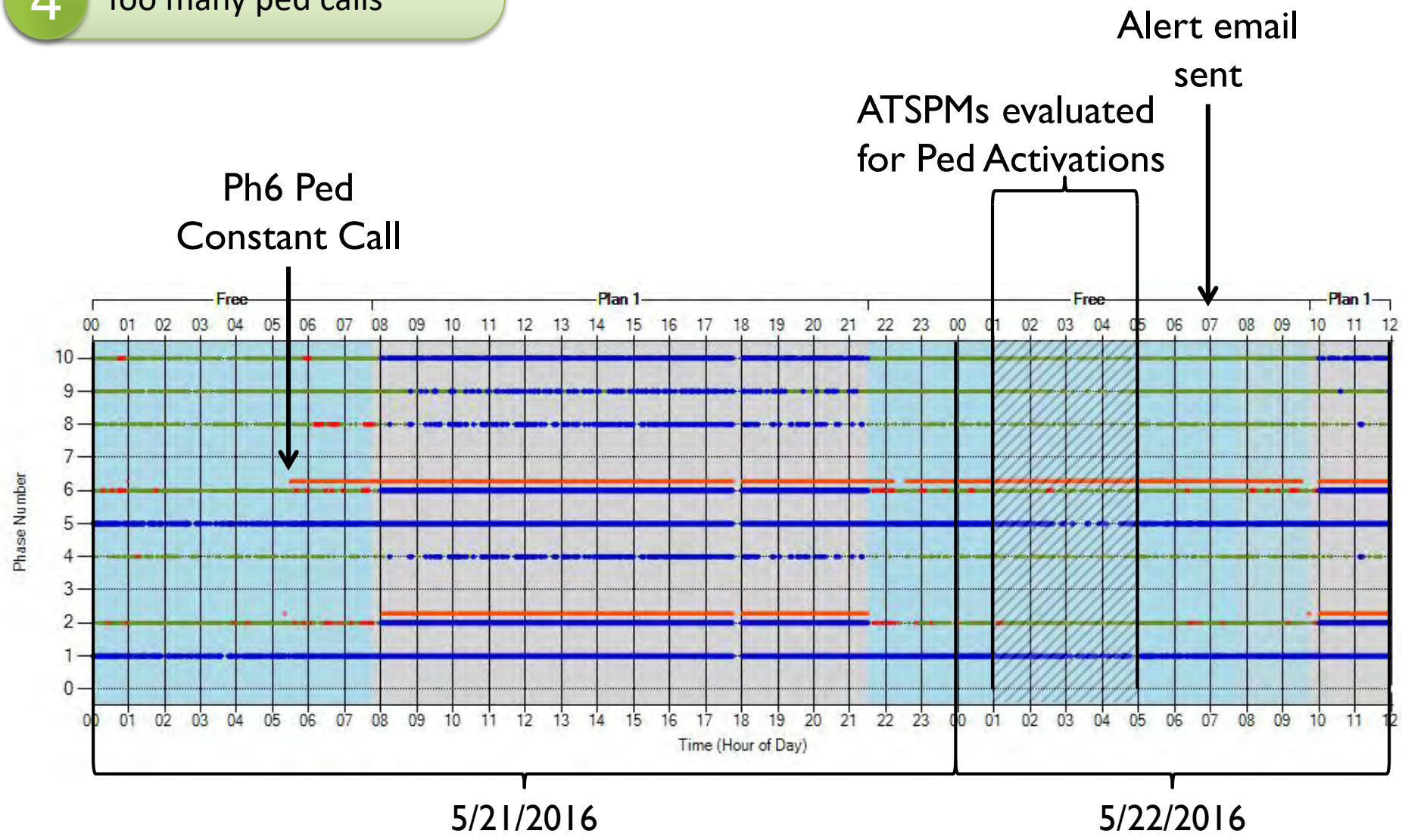


2 Too many max outs

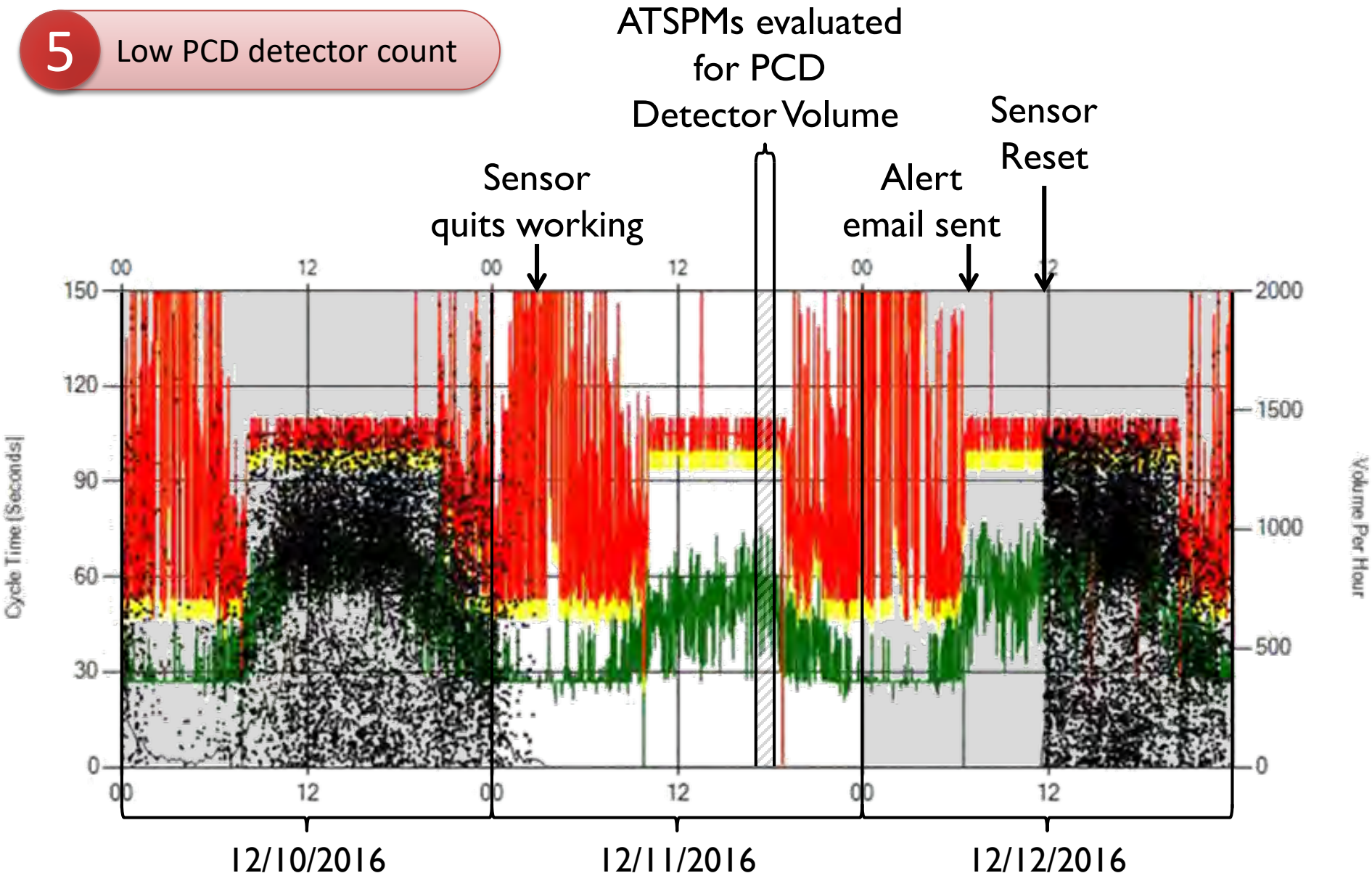


- Gap out
- Max out
- Force off
- Pedestrian activation (shown above phase line)
- Skip

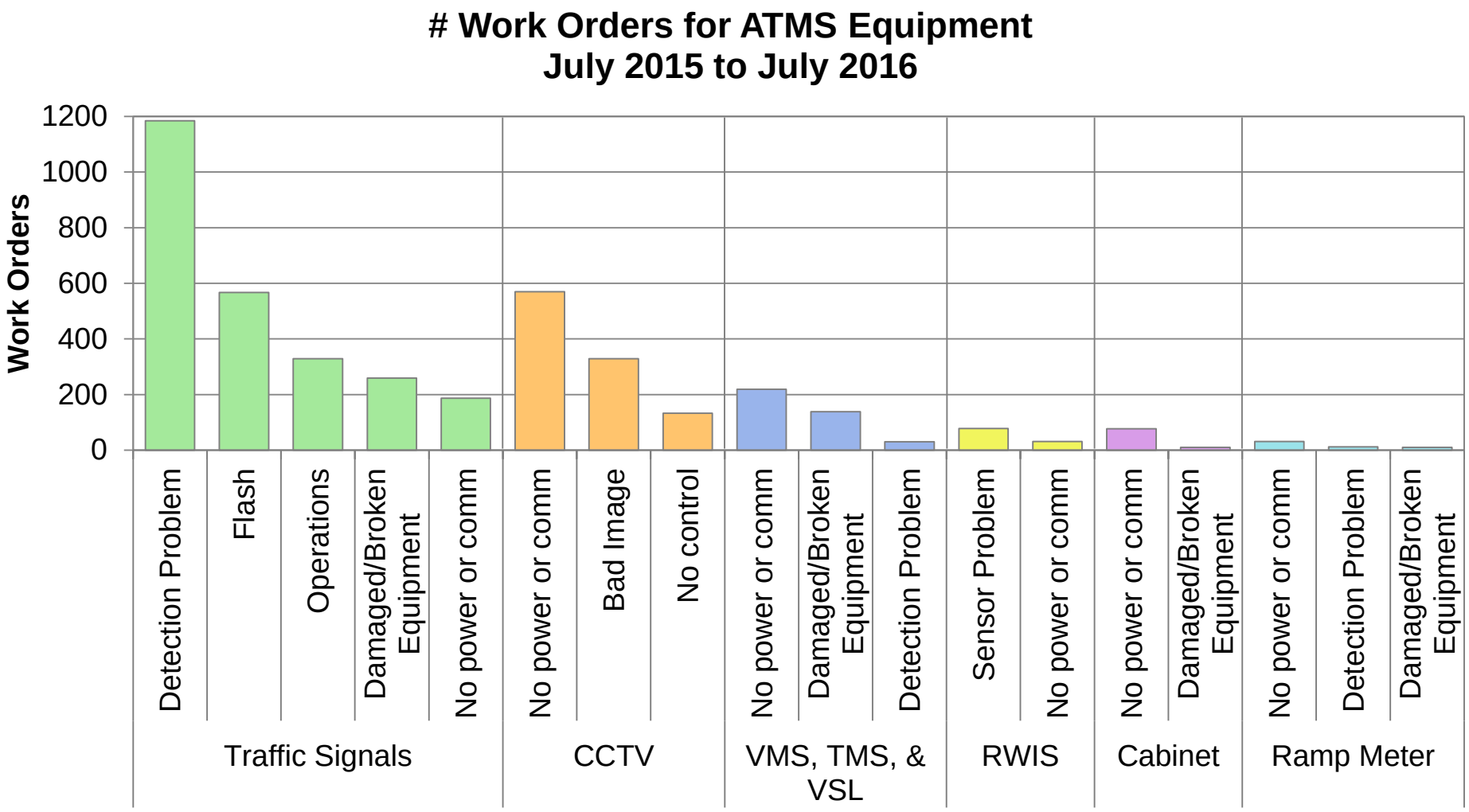
4 Too many ped calls



5 Low PCD detector count

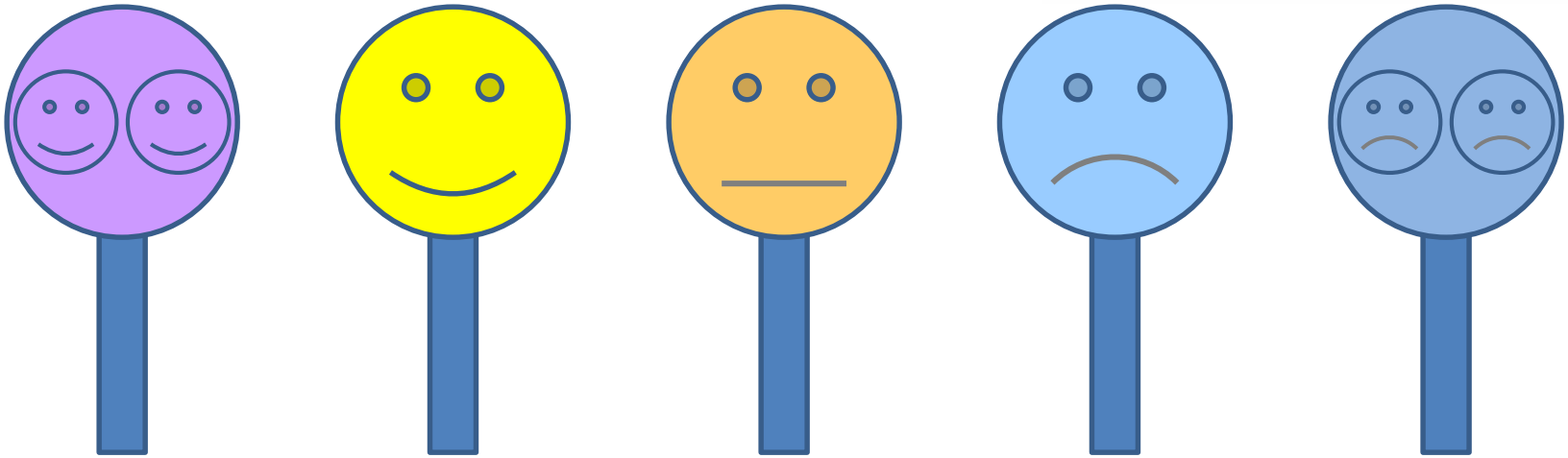


Work Orders


Work Orders for ATMS Equipment
July 2015 to July 2016
Work Orders
1200
1000
800
600
400
200
0
Detection Problem
Flash
Operations
Damaged/Broken Equipment
No power or comm
No power or comm
Bad Image
No control
No power or comm
Damaged/Broken Equipment
Detection Problem
Sensor Problem
No power or comm
No power or comm
Damaged/Broken Equipment
No power or comm
Detection Problem
Damaged/Broken Equipment
Traffic Signals
CCTV
VMS, TMS, & VSL
RWIS
Cabinet
Ramp Meter

UDOT Signal Timing Focus Group (July 2014)

- *How do you feel about UDOT?*
- *How do traffic signals make you feel?*



Focus Group Key Findings (July 2014)

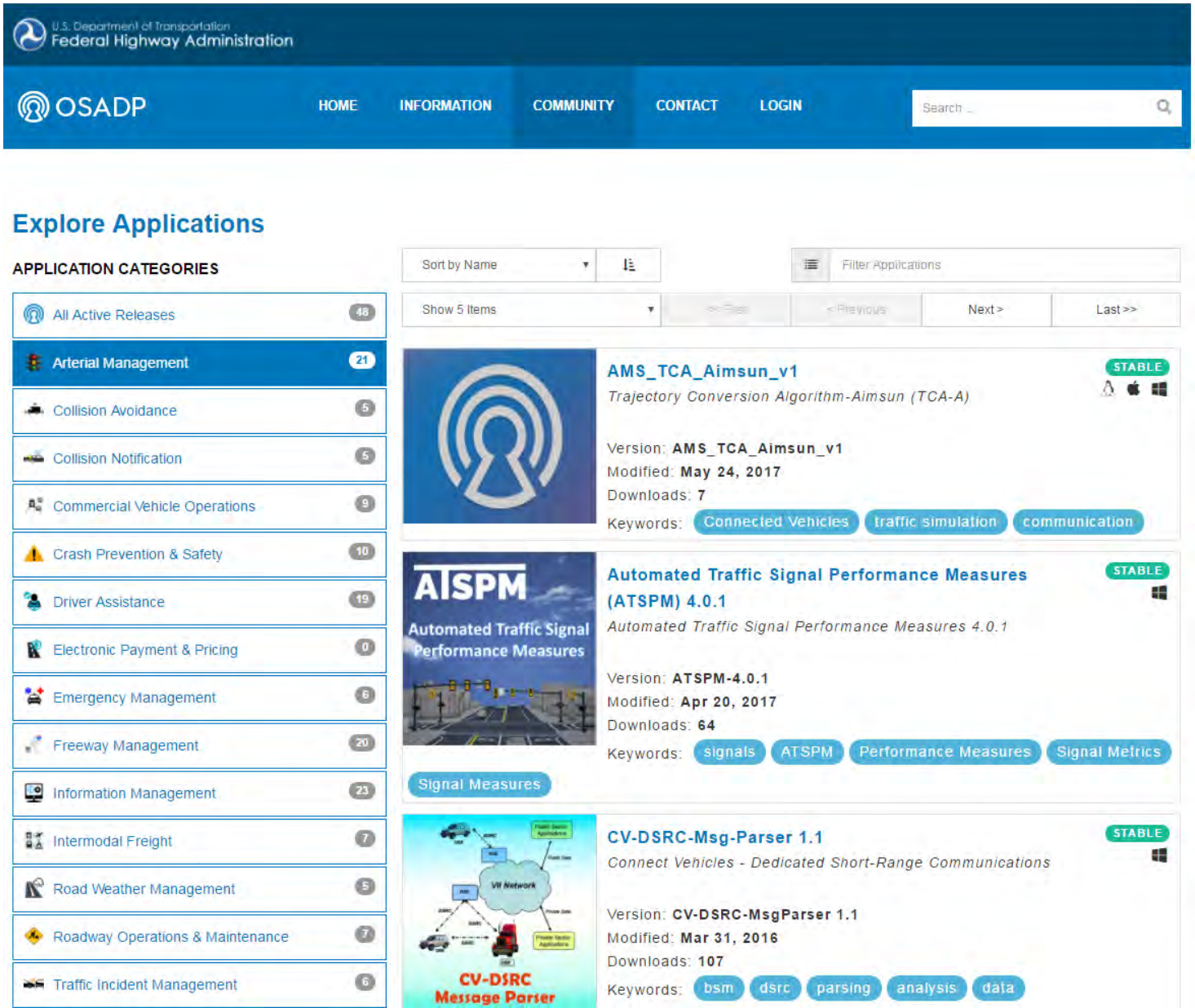
- UDOT is perceived positively, with innovation as the primary driver of positive impressions.
- Drivers believe traffic signal synchronization is improving.
- Drivers feel UDOT should be open about its accomplishments in a way that protects its credibility.

60s Commercial – Green Lights

http://udot.utah.gov/greenlights

UDOT ATSPM Source Code

https://www.itsforge.net



21 Installations of UDOT ATSPMs

Community Forums

National Operations Center of Excellence (NOCoE)
http://forum.transportationops.org/forum/5-traffic-signals/
➢General ATSPM topics (e.g. how to use metrics, detection setup, lessons learned, upcoming workshops & seminars, etc.)

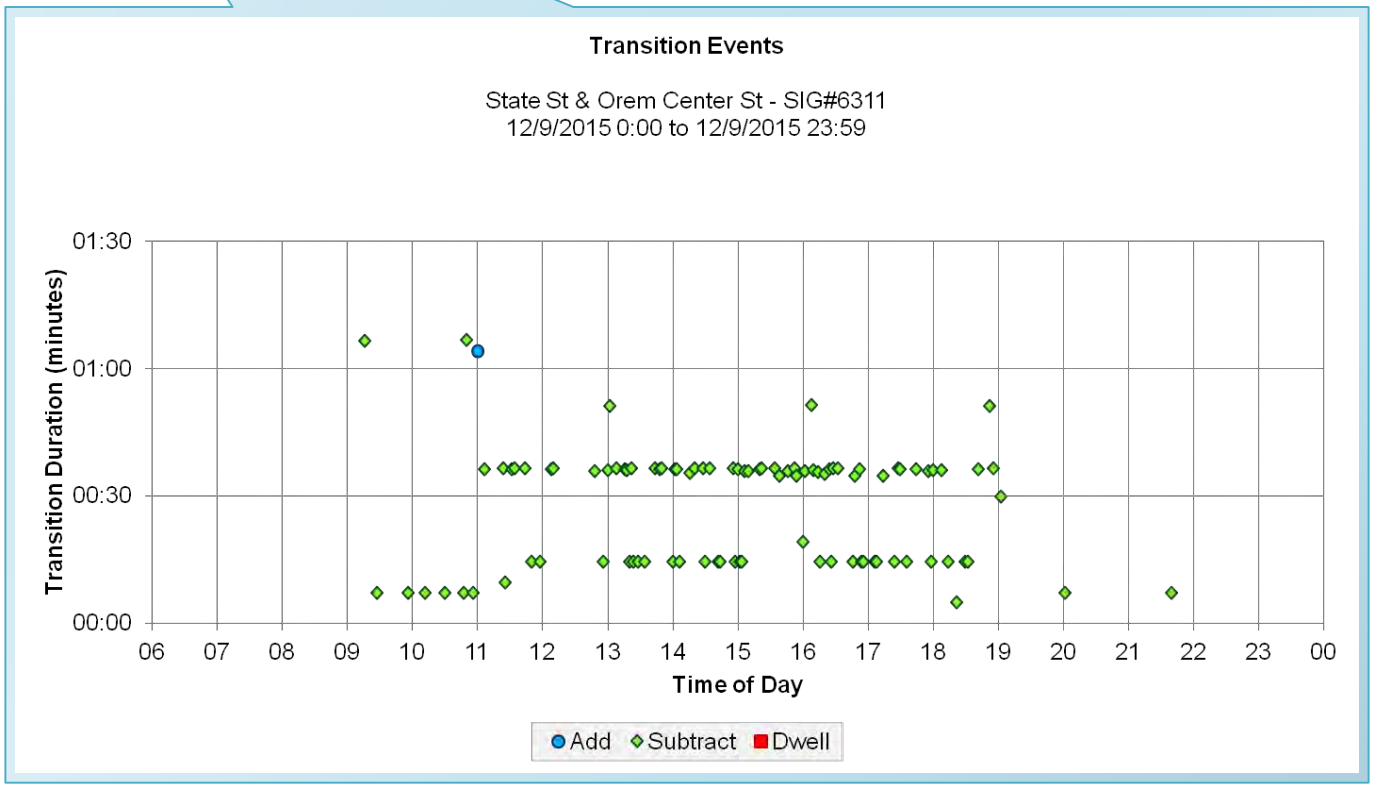
FHWA's Open Source Application Development Portal
https://www.itsforge.net/forum/ATSPM
➢Questions regarding UDOT's ATSPM source code (e.g. problems with installations, bugs, plans for future development, etc.)

What's Next

- New Metrics
  - Transition
  - Transit Signal Priority
- Watchdog analytics (GDOT)
- 15-minute data aggregation
- High-level reporting and alerts

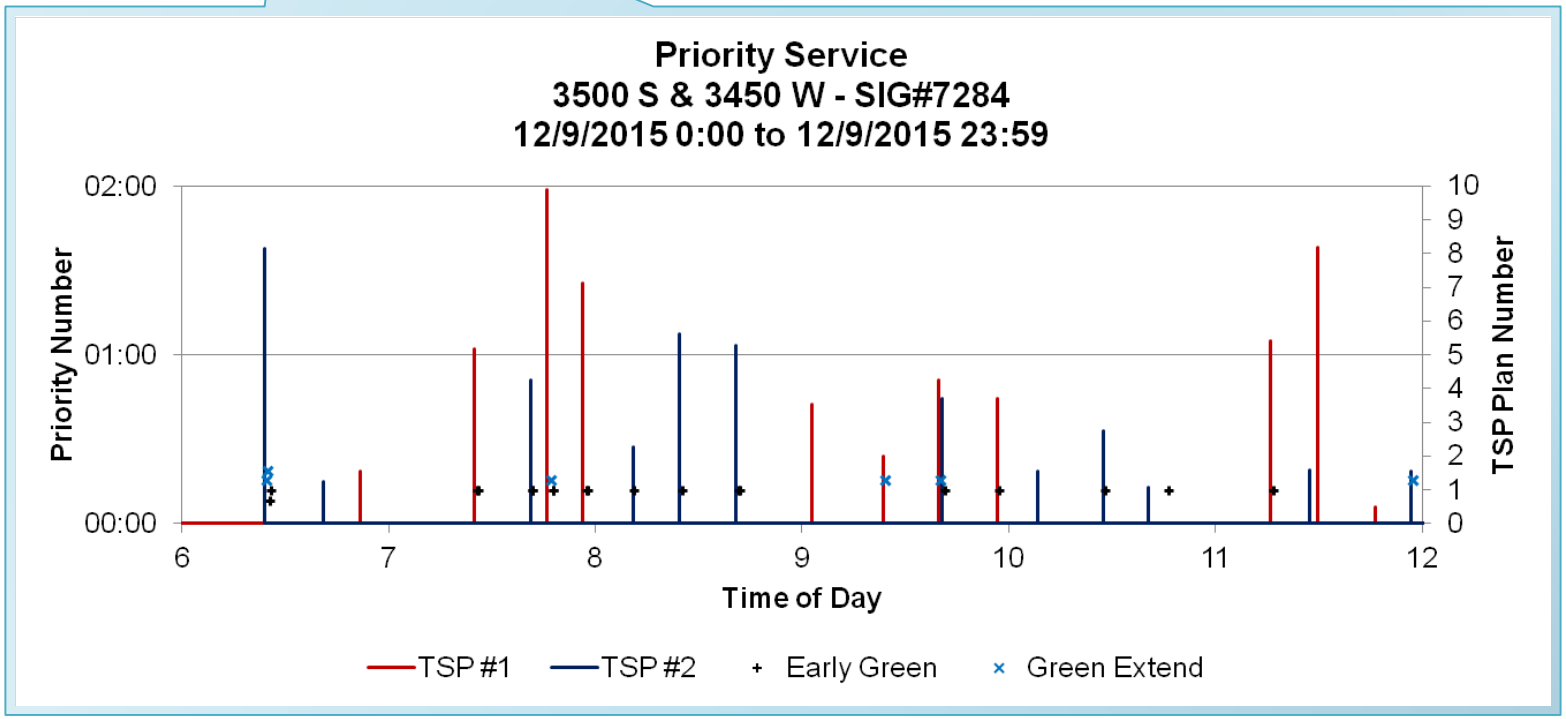
What's Next

- New Metrics
  - **Transition**
  - Transit Signal [illegible]rity
- Watchdog anal[illegible]OT)
- 15-minute data aggregation
- High-level reporting and alerts



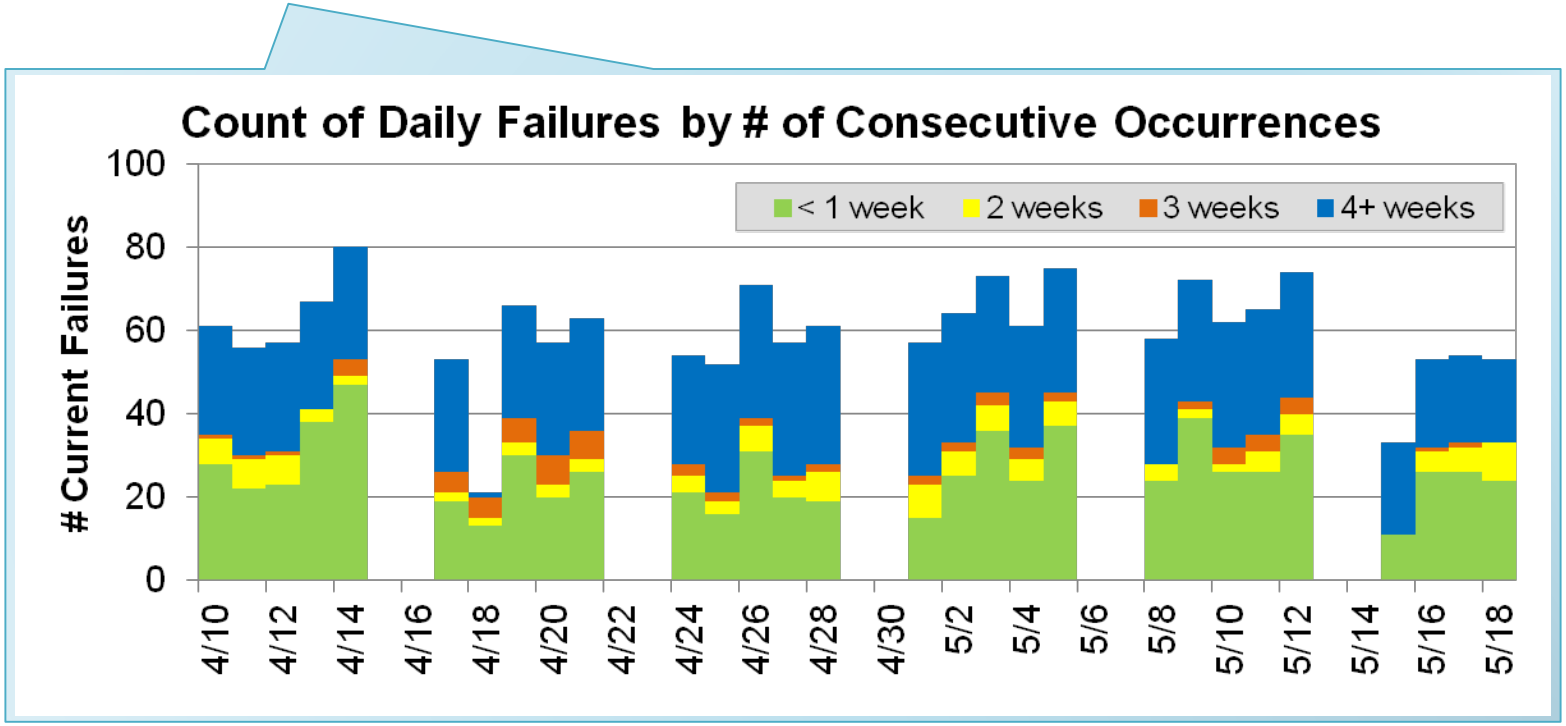
What's Next

- New Metrics
  - Transition
  - **Transit Signal Priority**
- Watchdog ana (GDOT)
- 15-minute data aggregation
- High-level reporting and alerts



What's Next

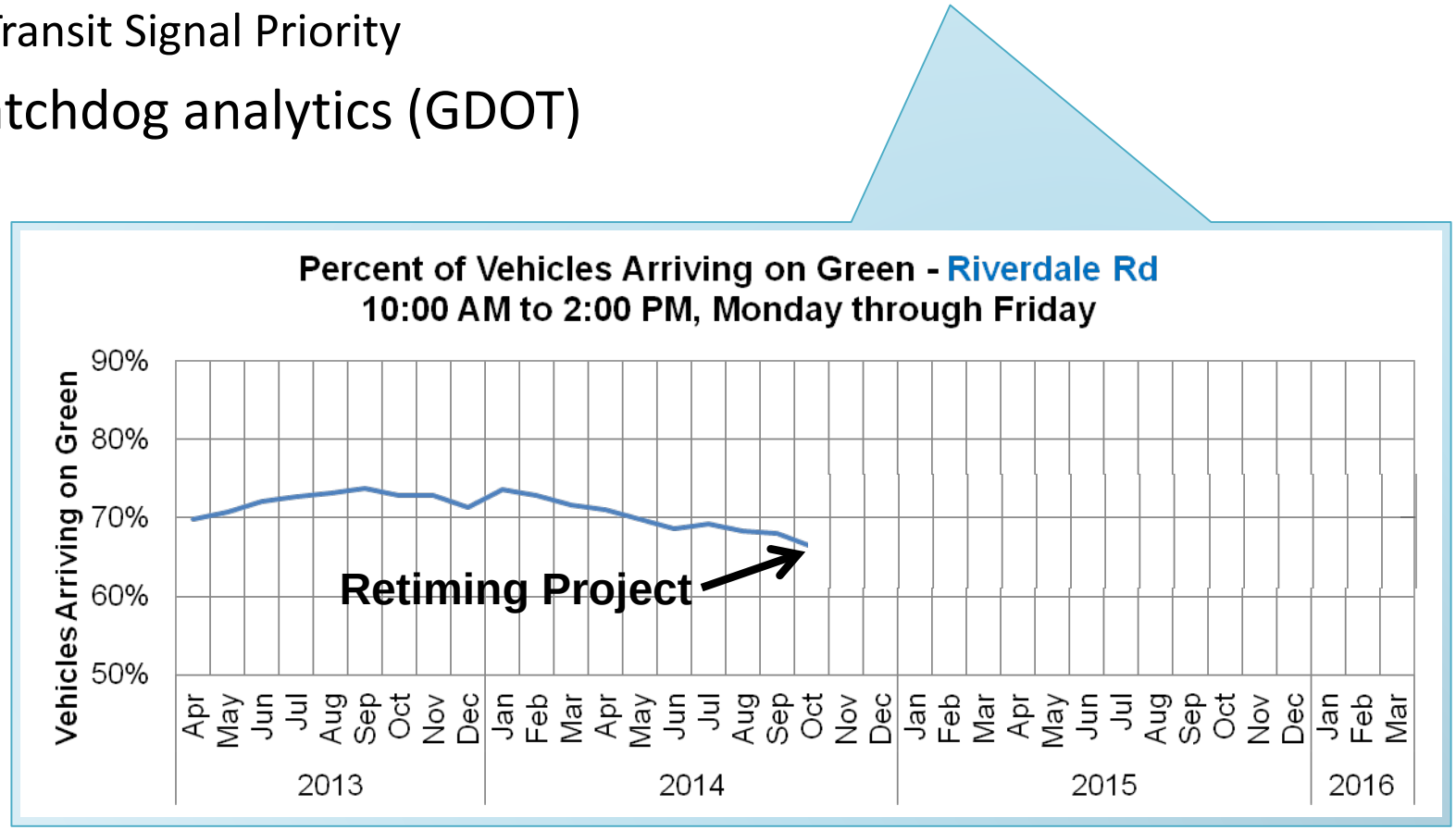
- New Metrics
  - Transition
  - Transit Signal Priority
- **Watchdog analytics (GDOT)**
- 15-minute data aggregation
- High-level reporting and alerts



What's Next

- New Metrics
  - Transition
  - Transit Signal Priority
- Watchdog analytics (GDOT)

- **15-minute data aggregation**
- **High-level reporting and alerts**



More Information

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UDOT ATSPMs

ATSPM Website
http://udottraffic.utah.gov/ATSPM

Green Lights Commercial
http://udot.utah.gov/greenlights

FHWA's Open Source Application Development Portal (OSADP)
https://www.itsforge.net

ATSPM Forums

National Operations Center of Excellence (NOCoE)
http://forum.transportationops.org/forum/5-traffic-signals/
- General ATSPM topics

FHWA's Open Source Application Development Portal (OSADP)
https://www.itsforge.net/forum/ATSPM
- Questions regarding UDOT's ATSPM source code

Crossing Guard Key Switch to Extend Walk Time

Emergency Response Plan – Additional support from non-technical personnel

2-3 per maintenance shed