

# UDOT Automated Traffic Signal Performance Measures (ATSPMs)

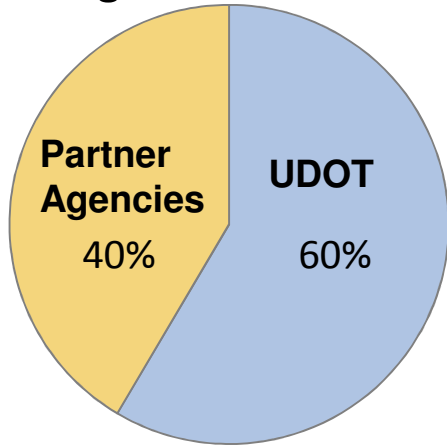
**Jamie Mackey**

UDOT Statewide Signal Engineer

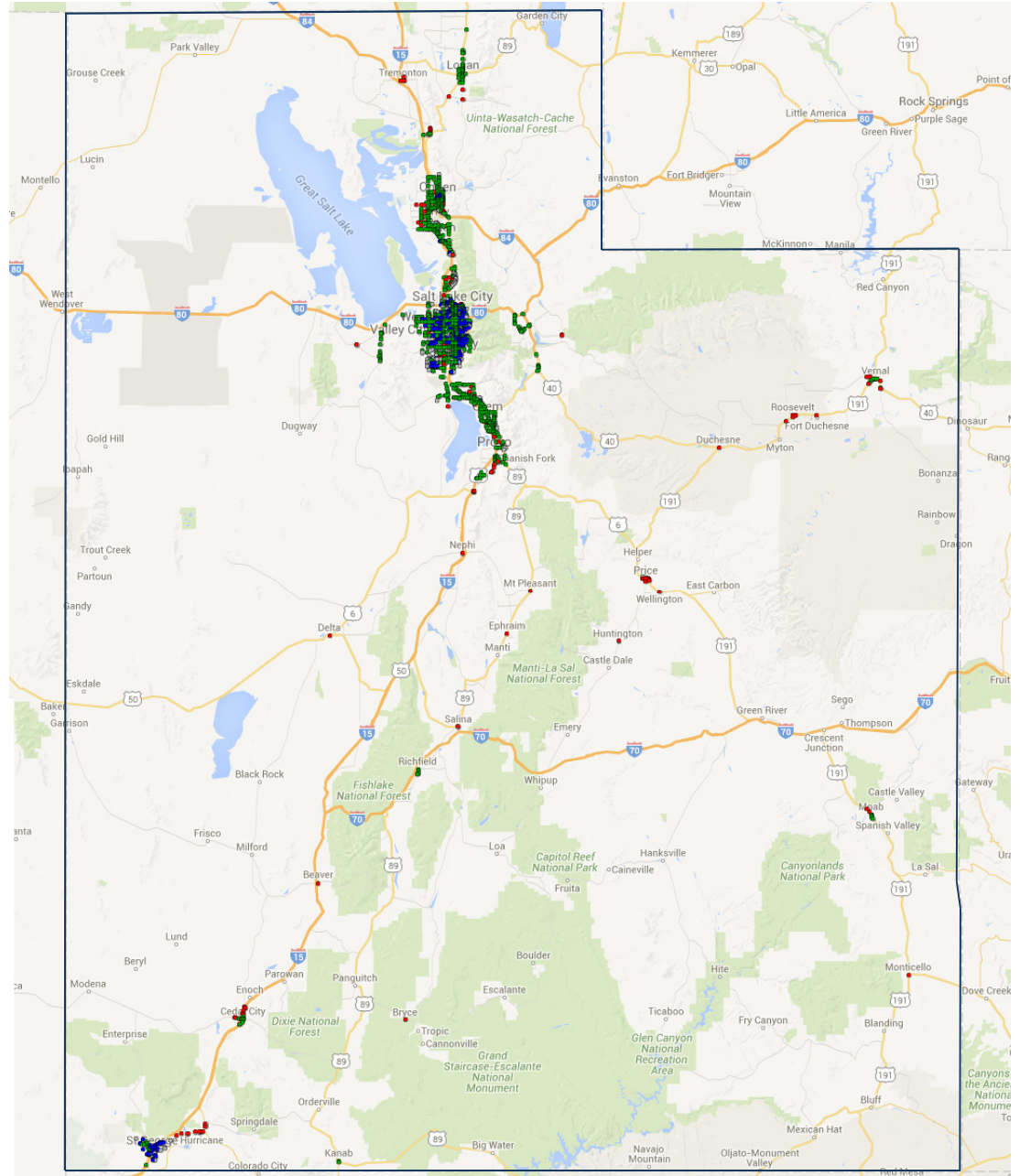
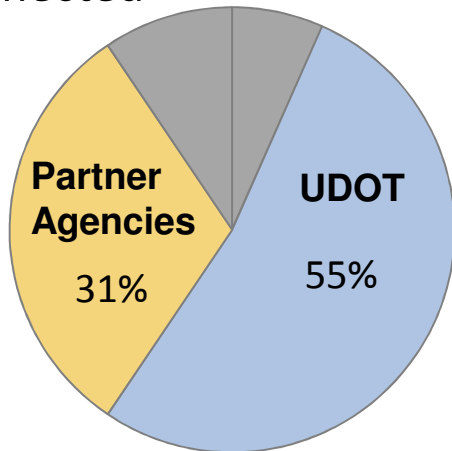
[jamiemackey@utah.gov](mailto:jamiemackey@utah.gov)

# Traffic Signals in Utah

1995 Traffic Signals



86% Connected



# 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 projects
- Proactive signal maintenance
- **Real-time monitoring of system health and quality of operations**

UTAH DEPARTMENT OF TRANSPORTATION

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WORLD CLASS  
TRAFFIC SIGNAL MAINTENANCE  
& OPERATIONS



QUALITY IMPROVEMENT TEAM  
Final Report

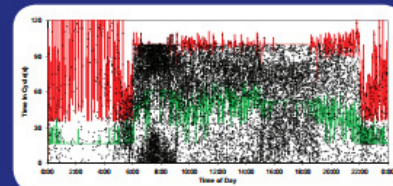
July 2011





# PERFORMANCE MEASURES FOR TRAFFIC SIGNAL SYSTEMS

*An Outcome-Oriented Approach*



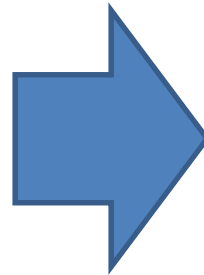
*Christopher M. Day, Darcy M. Bullock, Howell Li, Stephen M. Remias, Alexander M. Hainen, Richard S. Freije, Amanda L. Stevens, James R. Sturdevant, and Thomas M. Brennan*



# SPM 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

## 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

# Standard Controls

## 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 I
- 102 Preempt (Call) Input On
- 103 Preempt Gate Down Input R
- 104 Preempt (Call) Input Off
- 105 Preempt Entry Started

Purdue University  
Purdue e-Pubs

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JTRP Data Papers

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11-2012

## Indiana Traffic Signal Hi Resolution Data Logger Enumerations

James R. Sturdevant  
*INDOT, jsturdevant@indot.in.gov*

Timothy Overman  
*INDOT*

Eric Raamot  
*Econolite Group Inc.*

Ray Deer  
*Peck Traffic Corporation*

Dave Miller  
*Siemens Industry, Inc.*

*See next page for additional authors*

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### Recommended Citation

Sturdevant, J. R., T. Overman, E. Raamot, R. Deer, D. Miller, D. M. Bullock, C. M. Day, T. M. Brennan, H. Li, A. Hainen, and S. M. Remias. *Indiana Traffic Signal Hi Resolution Data Logger Enumerations*. Publication . , Indiana Department of Transportation and Purdue University, West Lafayette, Indiana, 2012. doi: <http://data.datacite.org/10.4231/K4RN3SSH>.

This document has been made available through Purdue e-Pubs, a service of the Purdue University Libraries. Please contact [epubs@purdue.edu](mailto:epubs@purdue.edu) for additional information.

# High-resolution Data

0.1-second resolution

	Timestamp	Event Code	Event Parameter
	6/27/2013 1:29:51.1	10	8
<b>Detector 5 ON</b>	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 1:29:53.3	81	6
	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 1:30:02.2	33	2
	6/27/2013 1:30:02.2	33	6
	6/27/2013 1:30:02.2	32	2
	6/27/2013 1:30:02.2	32	6
	6/27/2013 1:30:06.1	10	2
	6/27/2013 1:30:06.1	10	6
<b>Phase 8 GREEN</b>	6/27/2013 1:30:08.1	1	8
	6/27/2013 1:30:13.1	32	8
<b>Detector 5 OFF</b>	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



# System Requirements



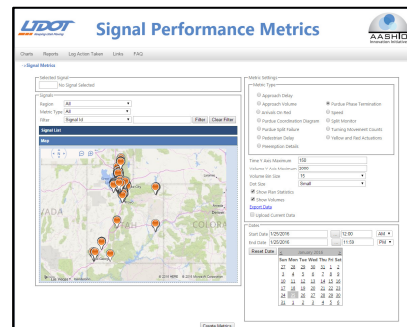
**High-resolution Controller**



**Communications**

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

**Server**



**Software**



**Detection  
 (optional)**

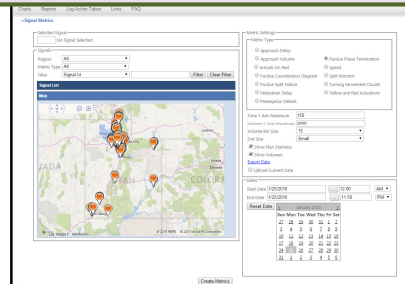
# System Requirements



**Does NOT require  
Central Traffic Signal  
Management Software!**

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

**Server**



**Software**

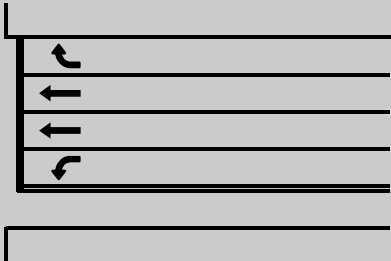
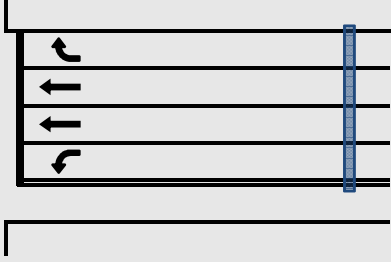
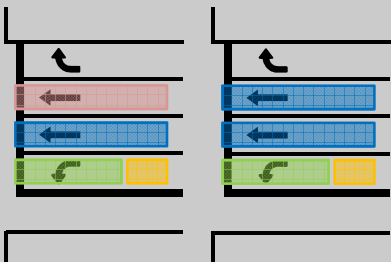
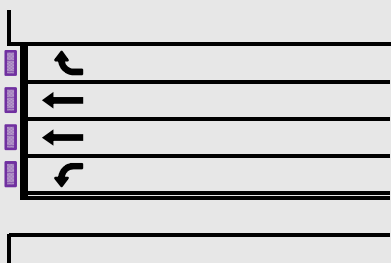


**Detection  
(optional)**

# Objective: Vendor Neutrality



# Metrics & Detection Requirements

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



## Detection

None

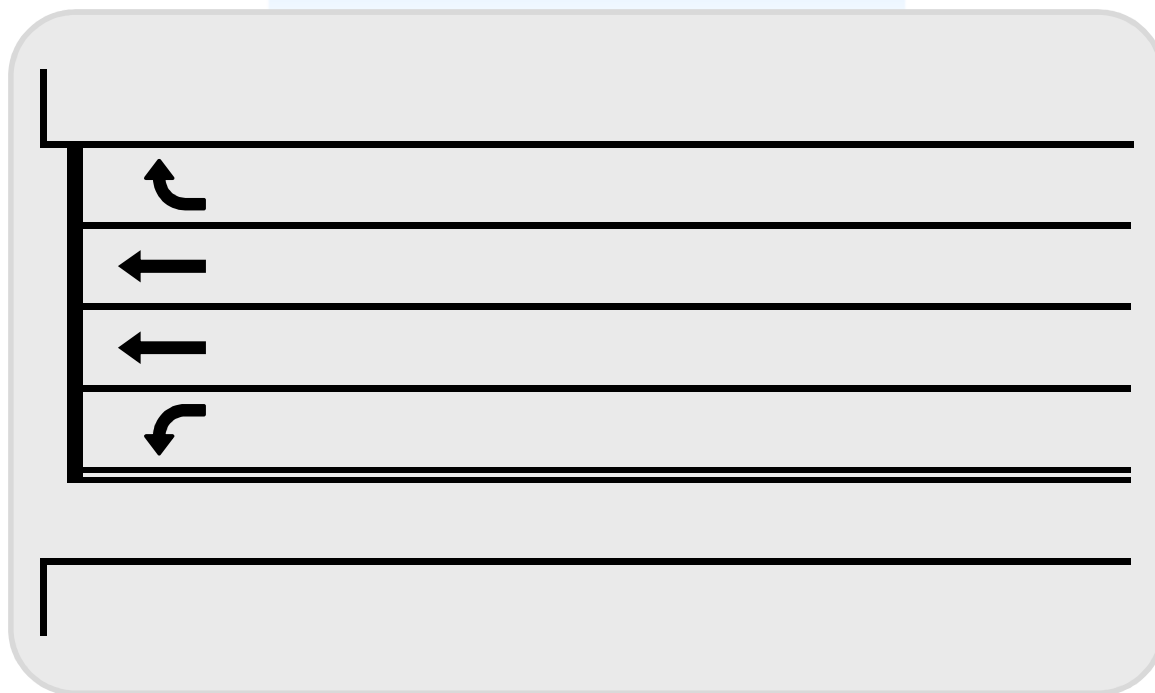
## Available Metrics

➤ Phase Termination Chart

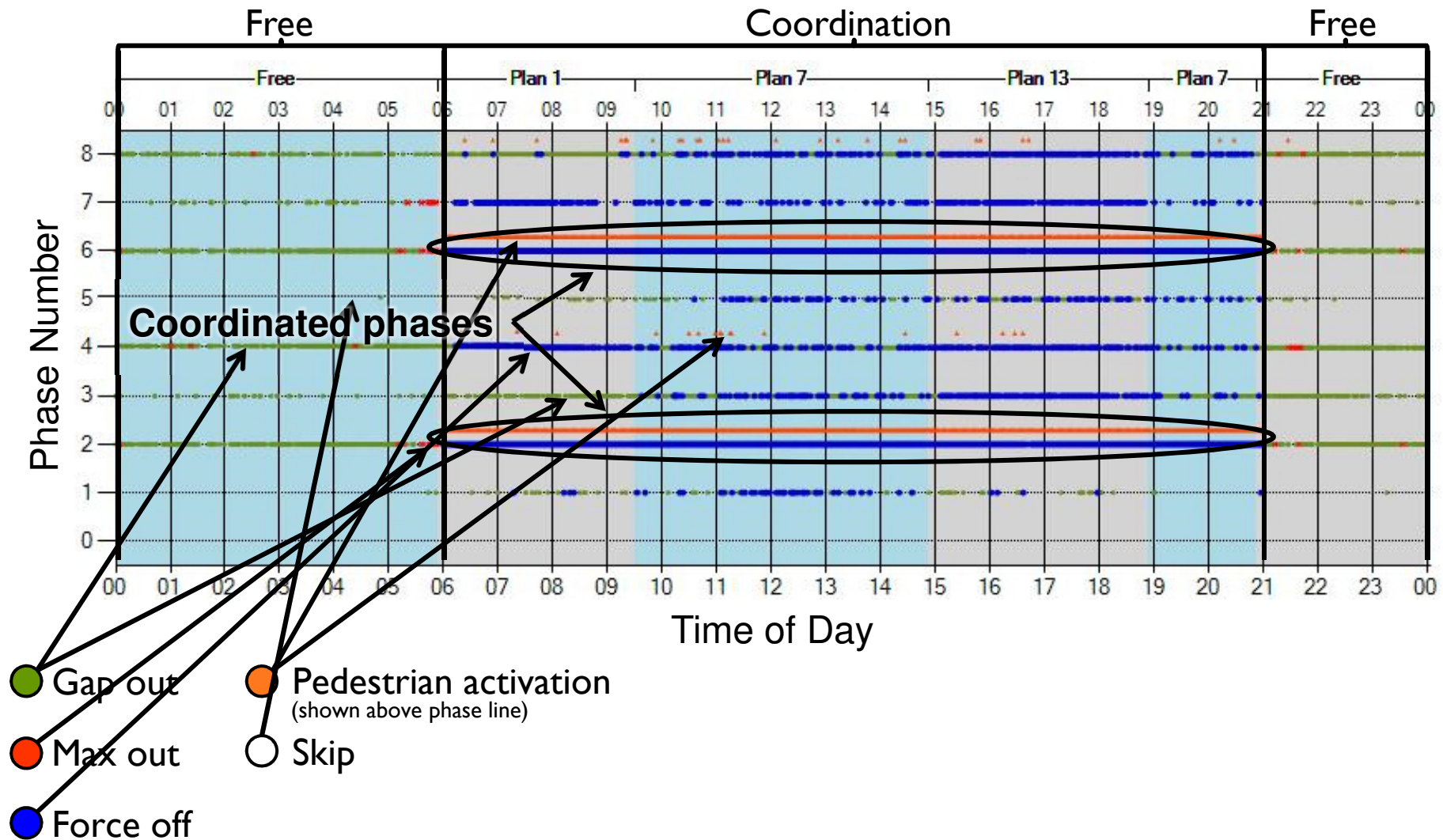
➤ Split Monitor

➤ Pedestrian Delay

➤ Preemption Details



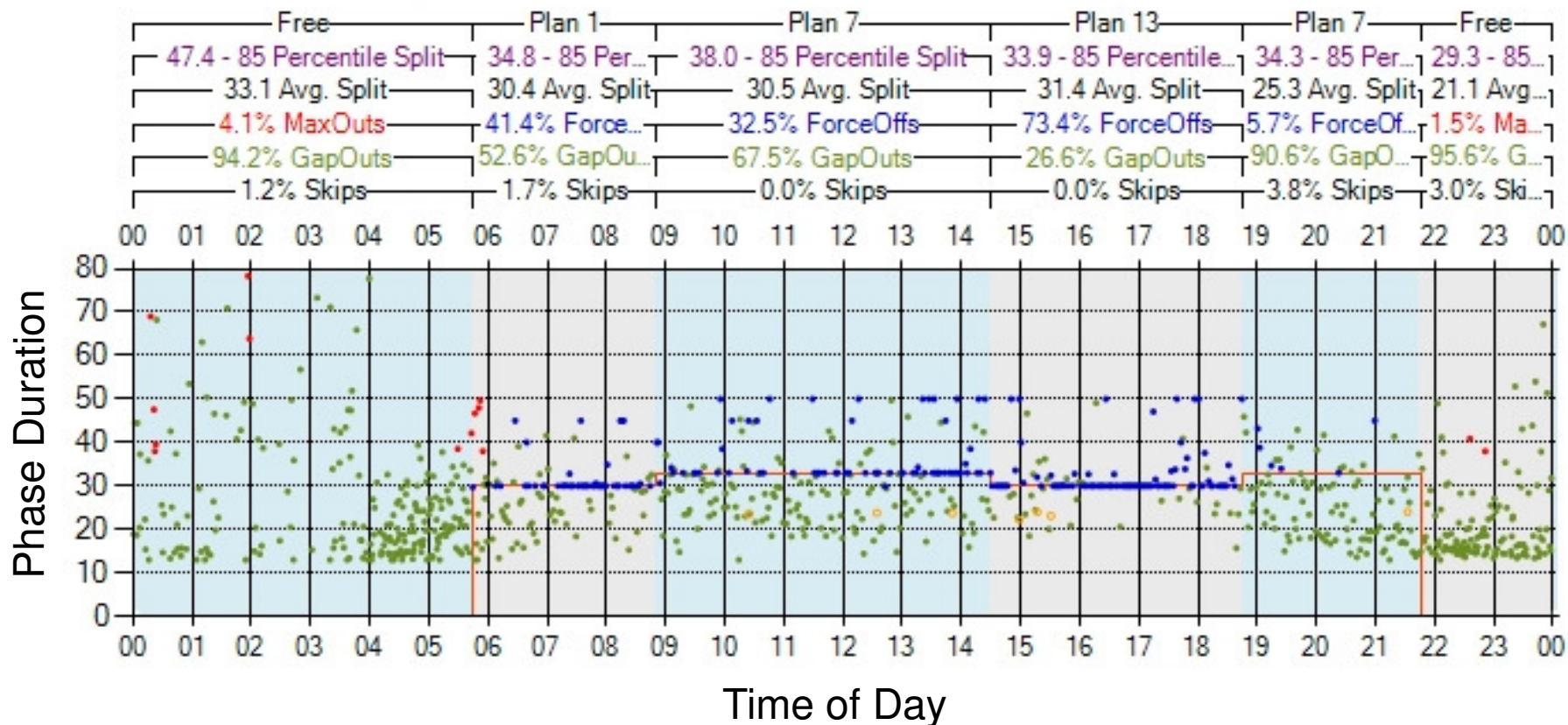
# Metric: Phase Termination Chart



# Metric: Split Monitor

**Phase 6**

US-89 2700 North SIG#5372 Phase 6  
 Wednesday, March 09, 2016 12:00 AM - Thursday, March 10, 2016 12:00 AM



## Detection

Setback Count Zones

## Available Metrics

➤ Purdue Coordination Diagram

➤ Approach Volume

➤ Arrivals on Red

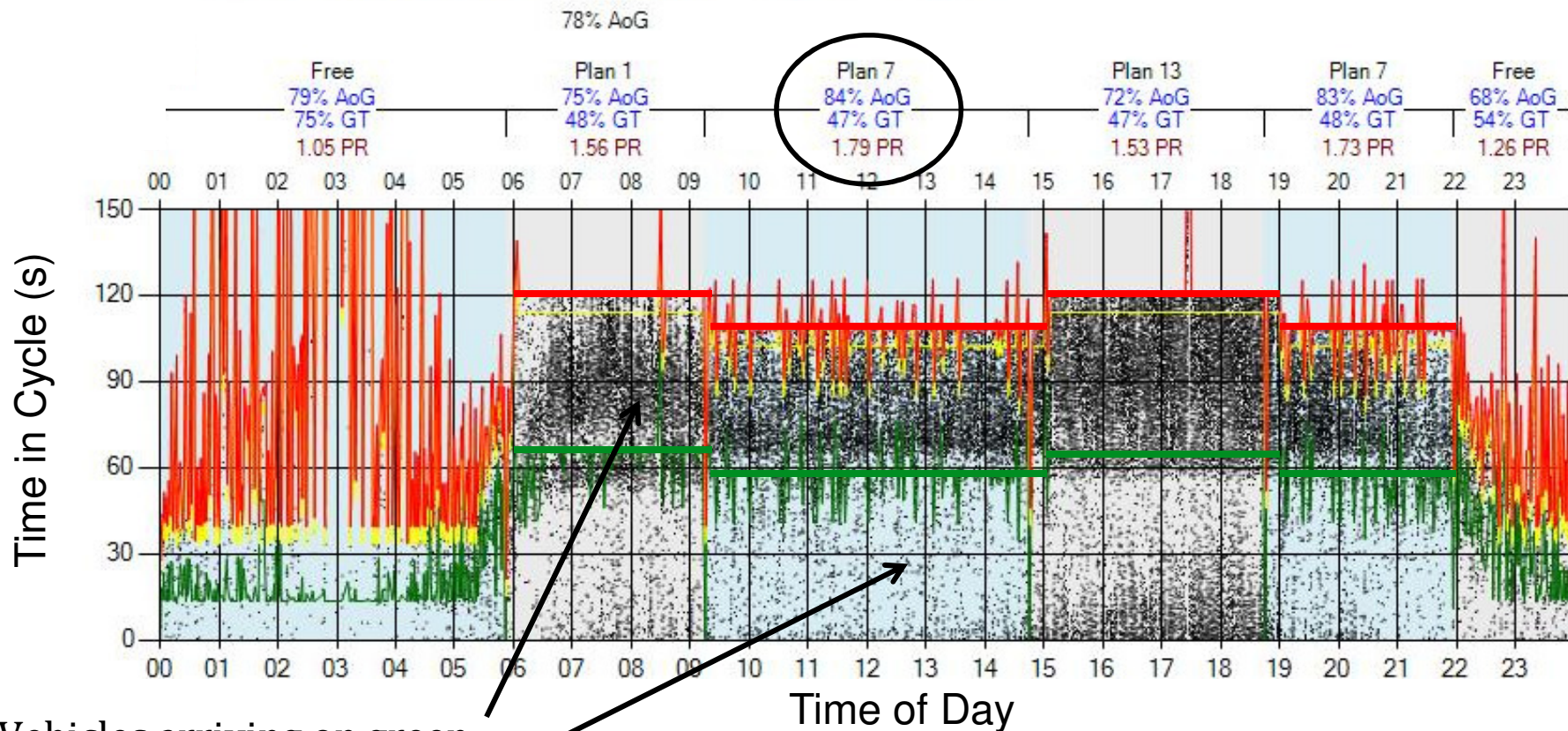
➤ Approach Delay





# Metric: Purdue Coordination Diagram

Bangerter Hwy (SR-154) 10400 South Signal 7364 Phase: 6 Southbound  
 Wednesday, September 03, 2014 12:00 AM - Wednesday, September 03, 2014 11:59 PM



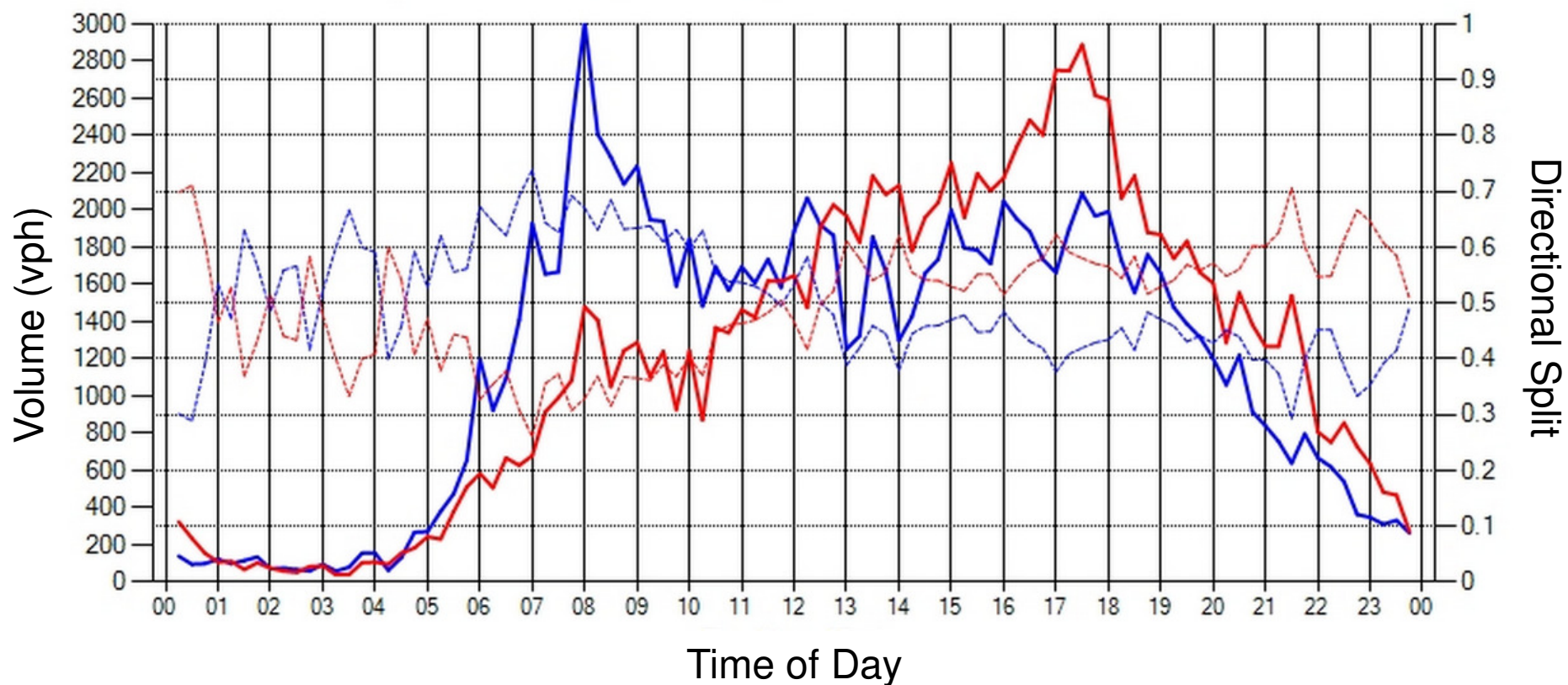
Vehicles arriving on green

Vehicles arriving on red



# Metric: Approach Volume

- Northbound
- Southbound
- - Northbound D-Factor
- - Southbound D-Factor

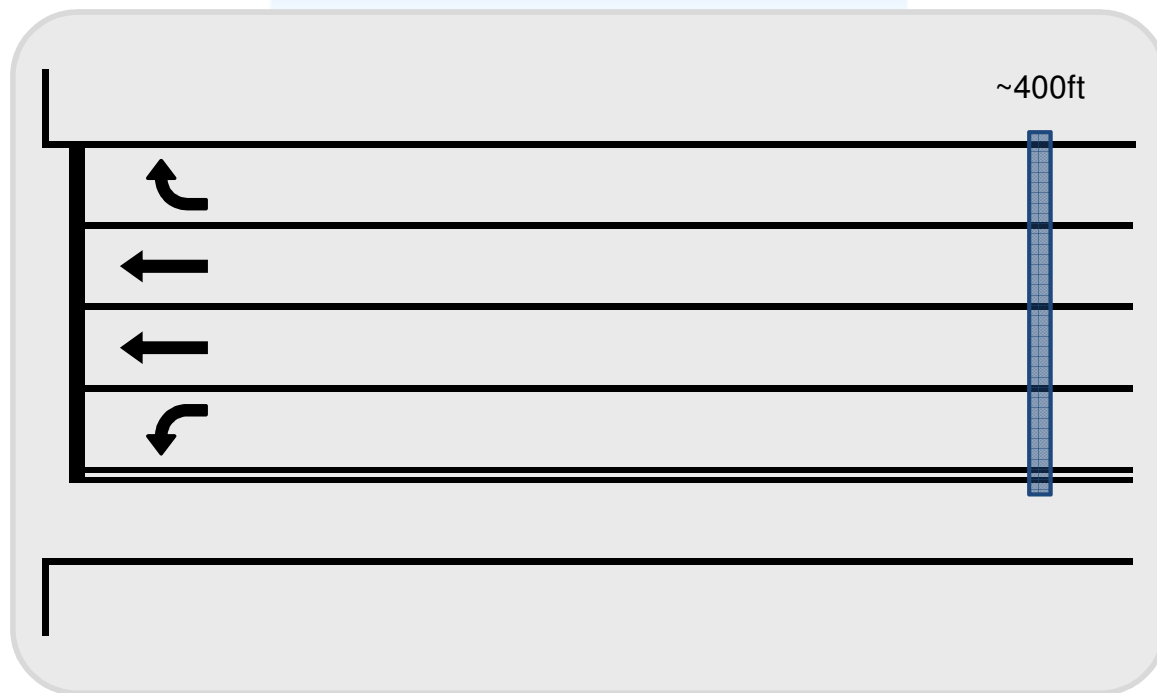


## Detection

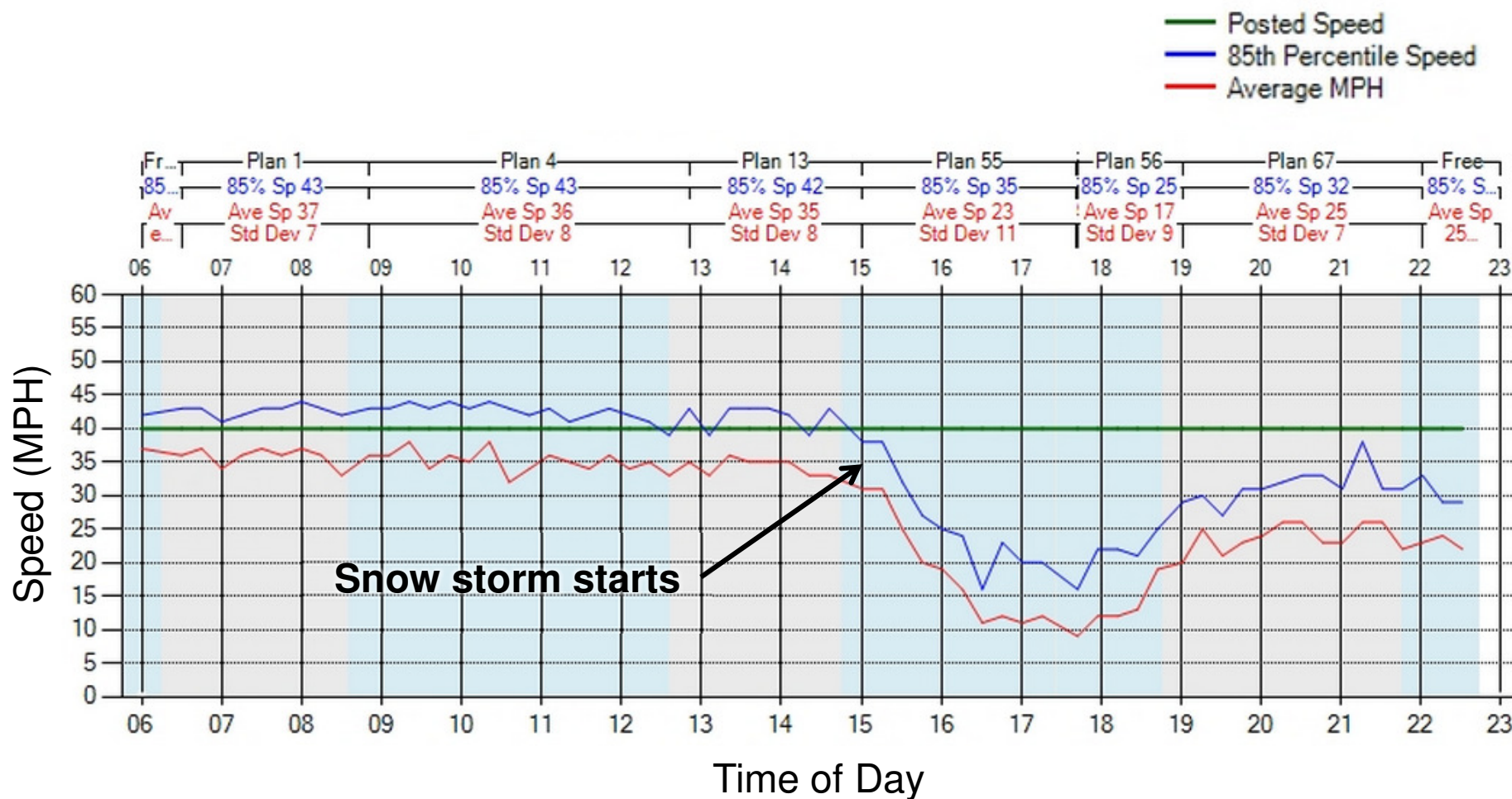
Setback Count Zones  
with speed

## Available Metrics

➤ Approach Speed



# Metric: Approach Speed



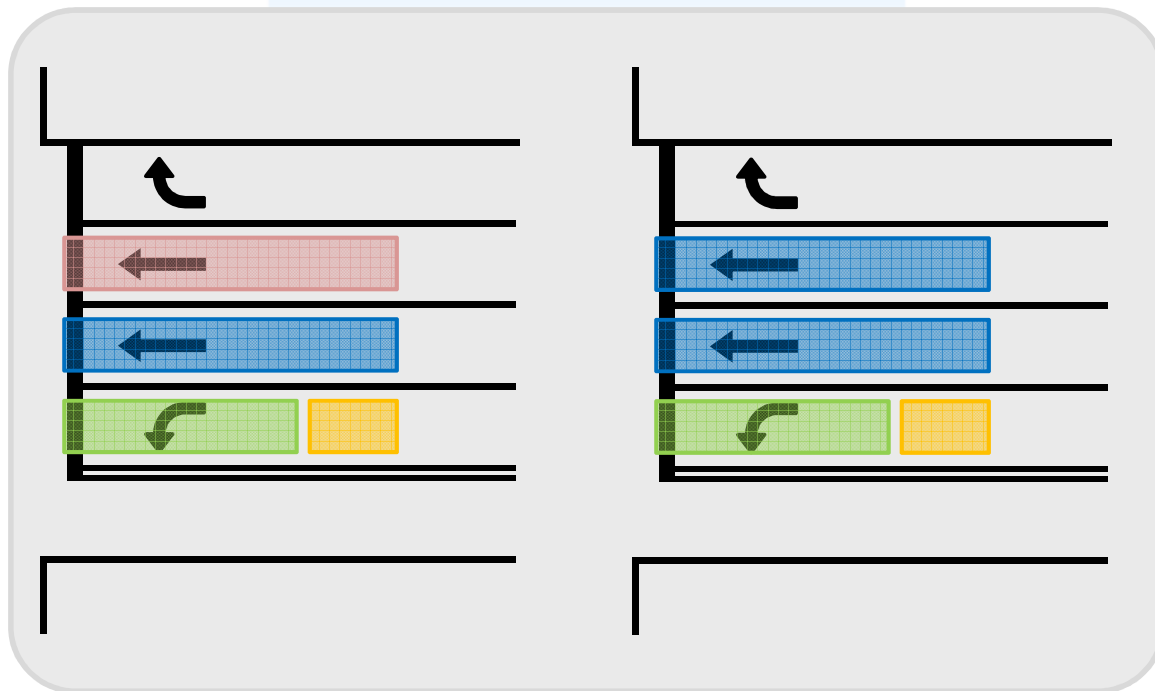
## Detection

Lane-by-lane Presence

Lane Group Presence

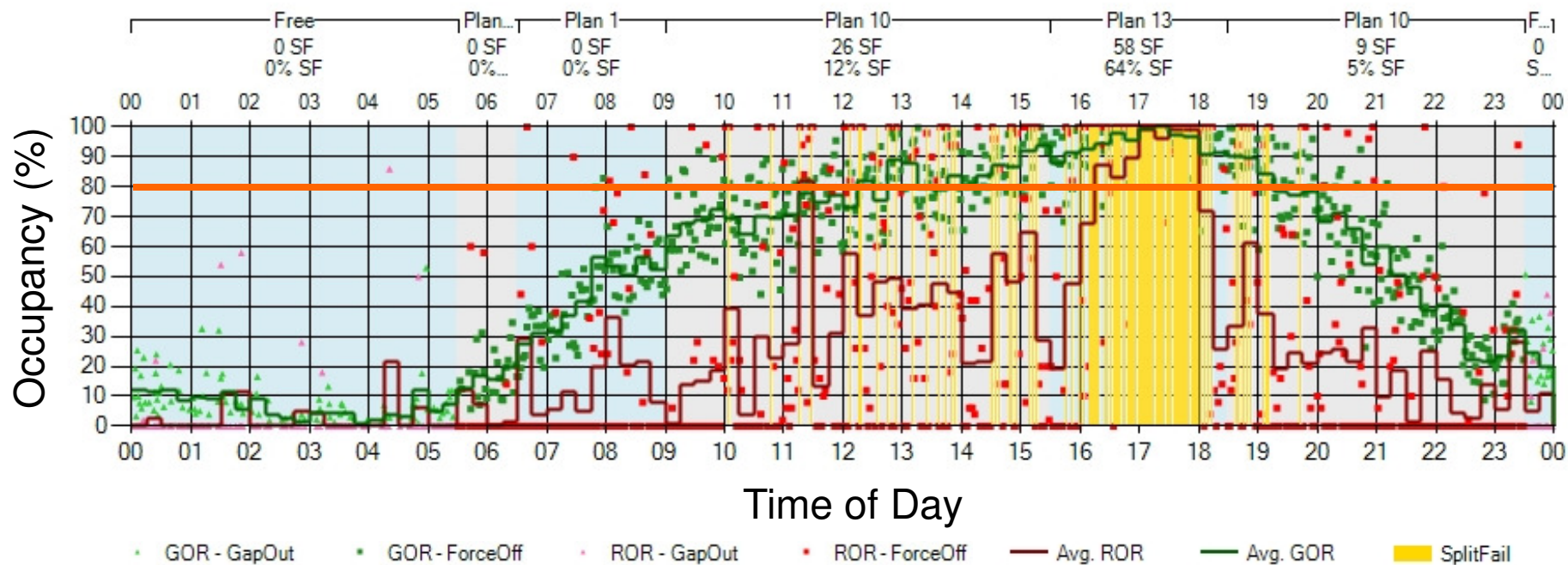
## Available Metrics

➤ Purdue Split Failure



# Metric: Purdue Split Failure

700 East 900 South Signal 7184 Phase: 6 Southbound  
 Wednesday, April 27, 2016 12:00 AM - Wednesday, April 27, 2016 11:59 PM  
 Total split fails for the selected period = 93




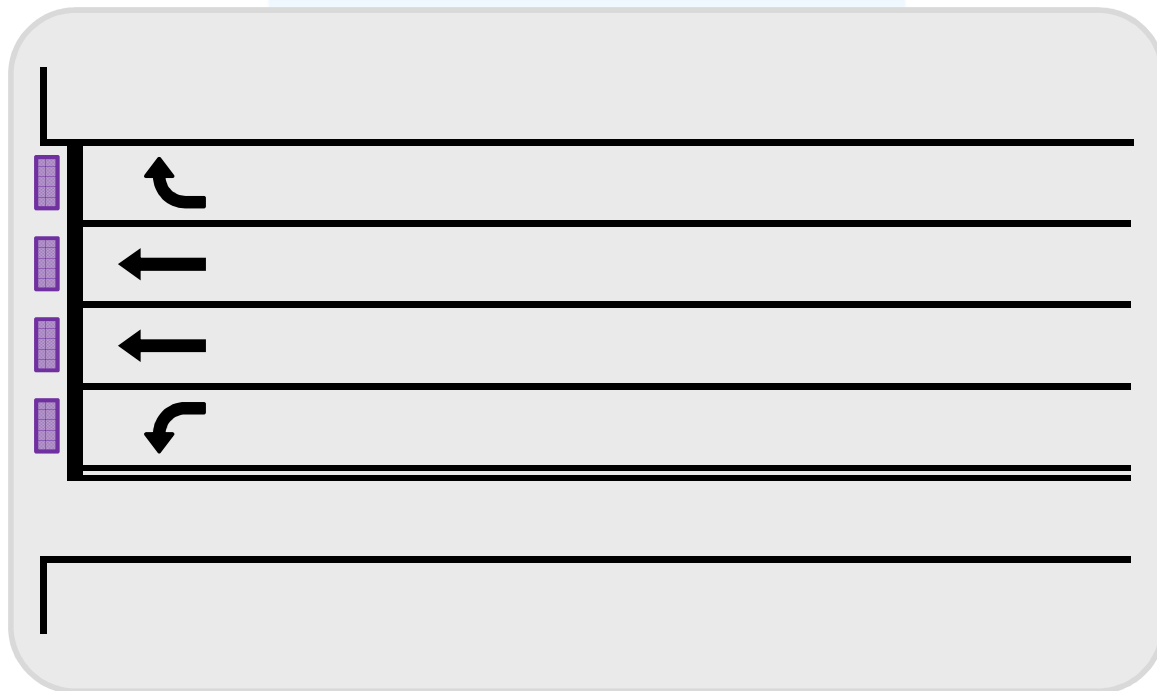


## Detection

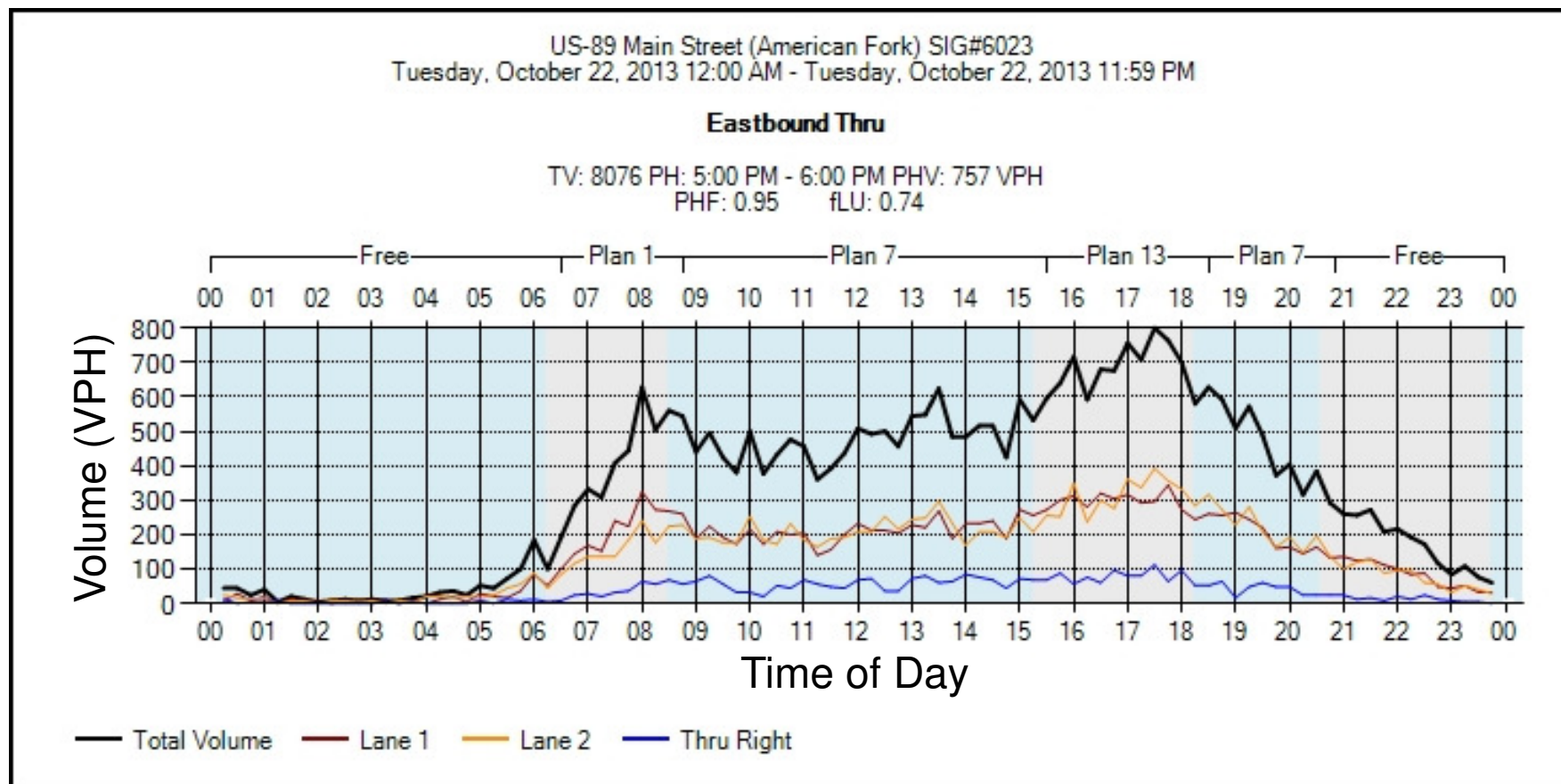
Lane-by-lane Count

## Available Metrics

 Turning Movement Counts



# Metric: Turning Movement Counts



**Metric: Turning Movement Counts**  
**Detection Requirements: Stop Bar Counters**

# System Health with SPMs

# System Health Alerts

1 No SPM Data

2 Too many max outs

3 Too many force offs

4 Too many ped calls

5 Low PCD detector count

## SPM Alerts for 5/22/2016

 SPMWatchdog@utah.gov

to marktaylor, me, signaldesk, shanejohnson, bryan.meenen, kbarnes, SWinters, tforbush, jay.smith,

--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:

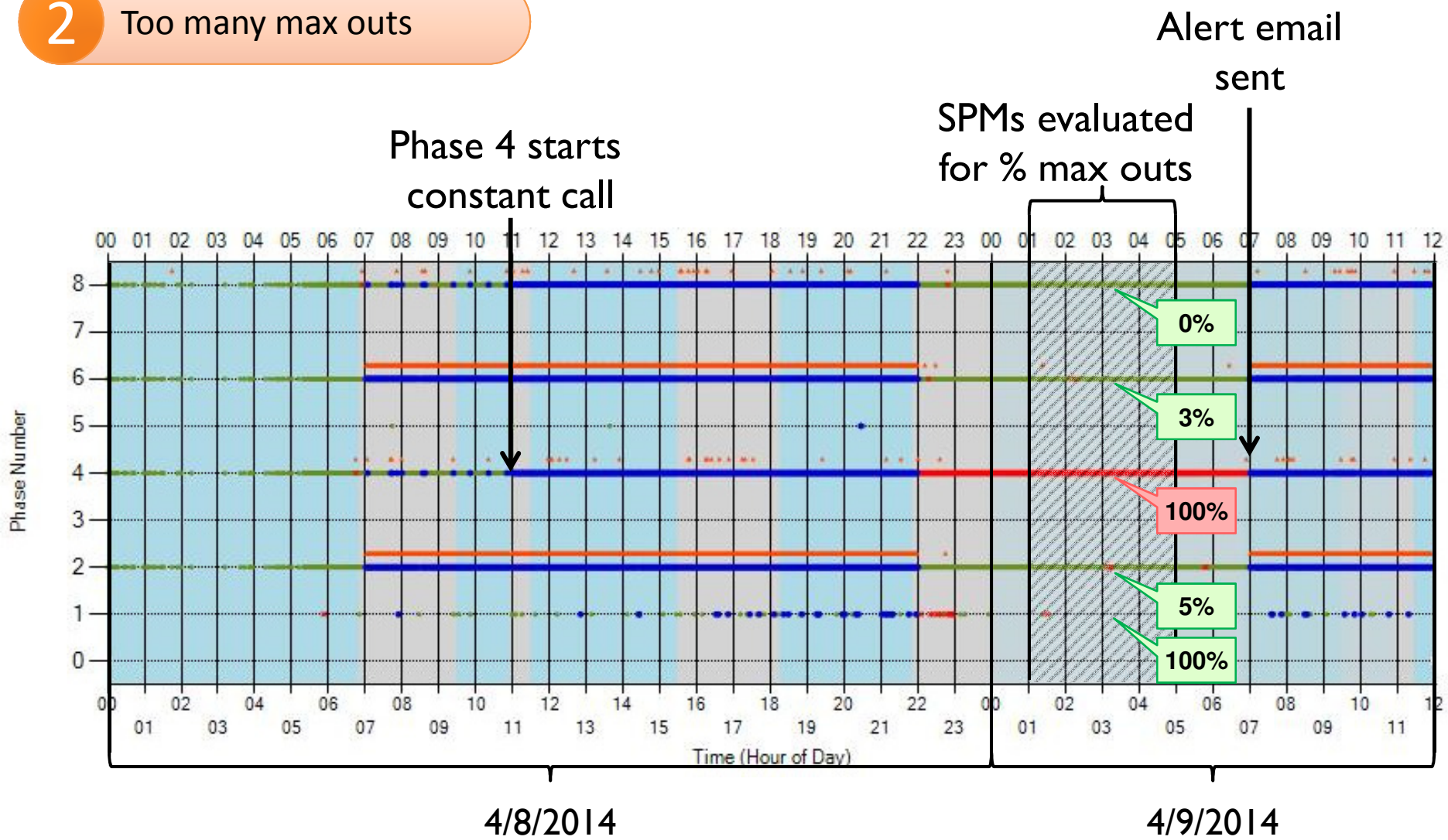
5134 - SR-193 (700 S) & I-15 NB (Clearfield) - Phase: 2 ( Has Unusually Low Counts. )  
7061 - Bangerter Hwy (SR-154) & 4100 South - Phase: 1 ( Has Unusually Low Counts. )  
7061 - Bangerter Hwy (SR-154) & 4100 South - Phase: 7 ( Has Unusually Low Counts. )  
7361 - Bangerter Hwy (SR-154) & 13400 South - 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 )



**2** Too many max outs

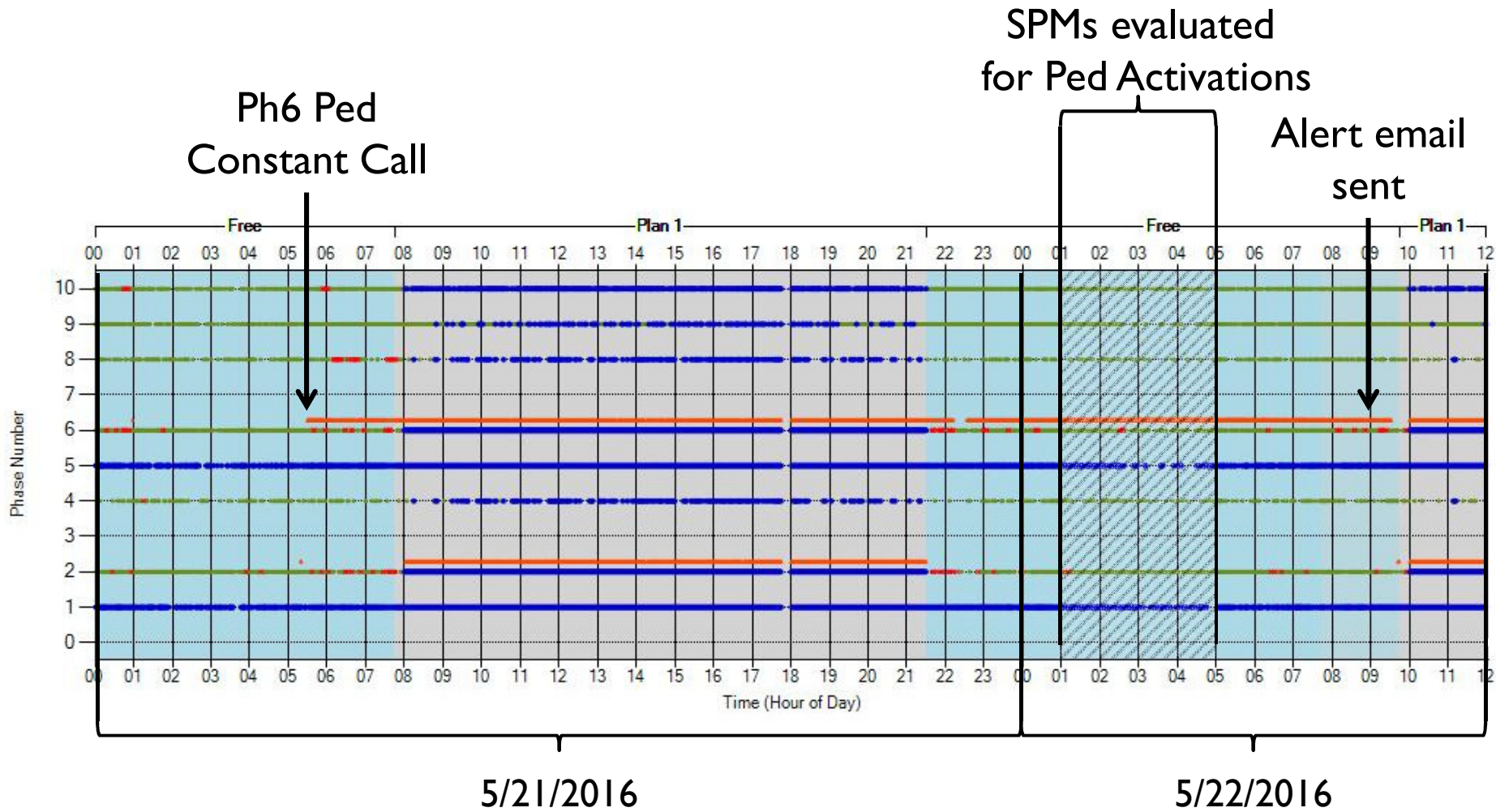


- Gap out
- Pedestrian activation (shown above phase line)
- Max out
- Force off
- Skip

**Metric: Purdue Phase Termination**  
**Detection Requirements: None**

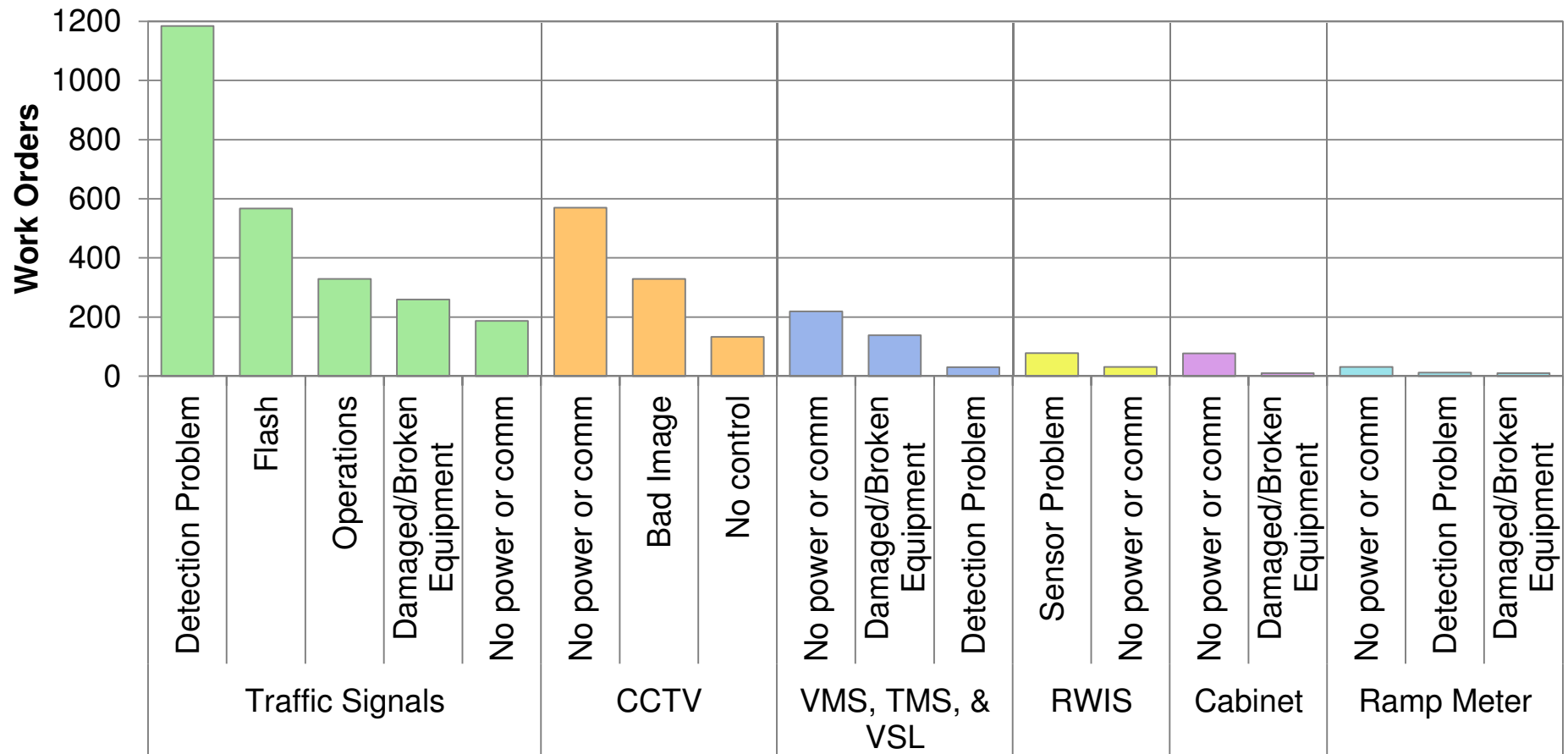


**4** Too many ped calls



# Work Orders for UDOT ATMS

# Work Orders for ATMS Equipment  
July 2015 to July 2016

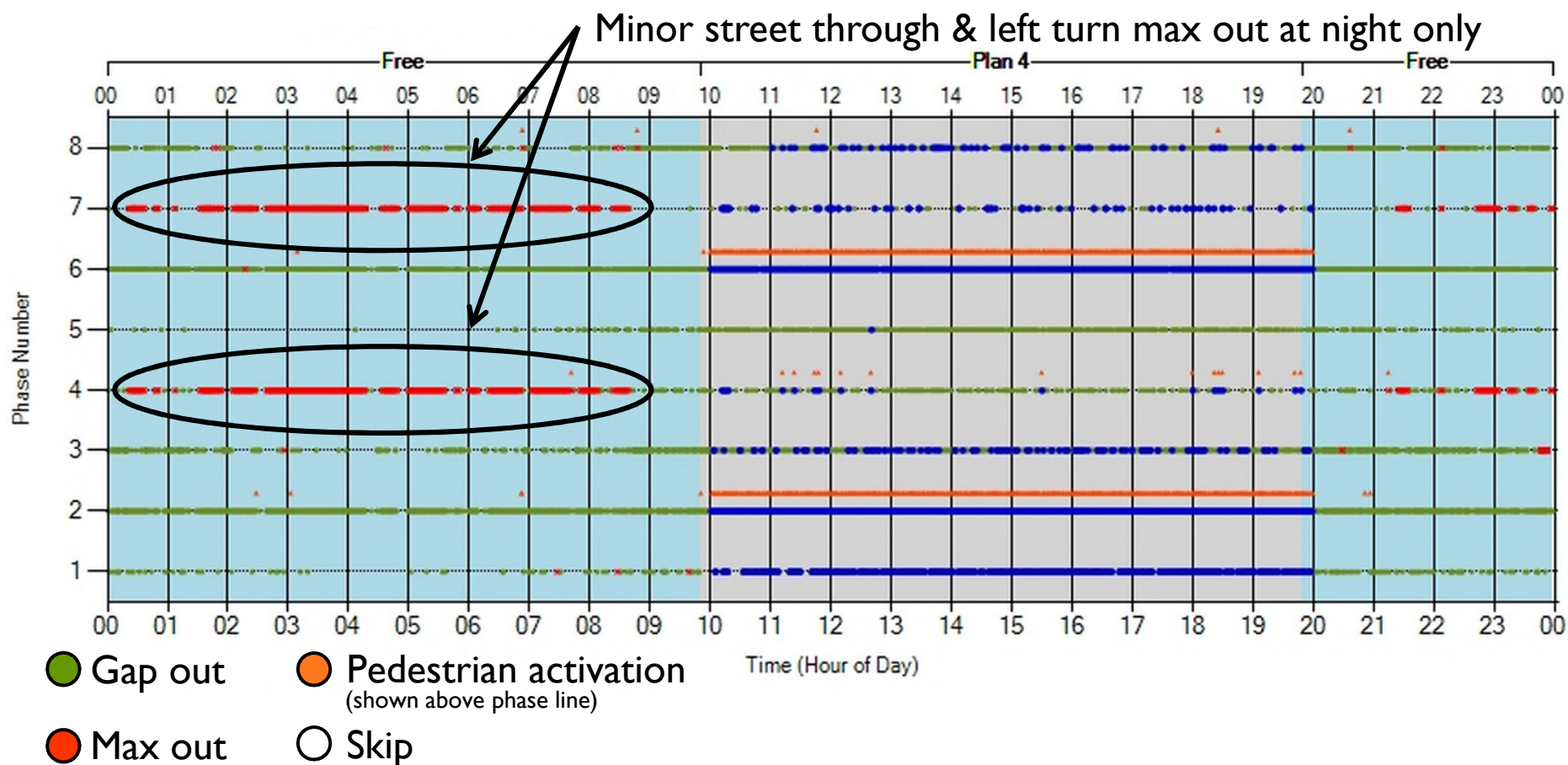


# Troubleshooting with SPMs

# Complaint: Long red at 2 a.m., no other traffic

**Before**

Video detection not working at night

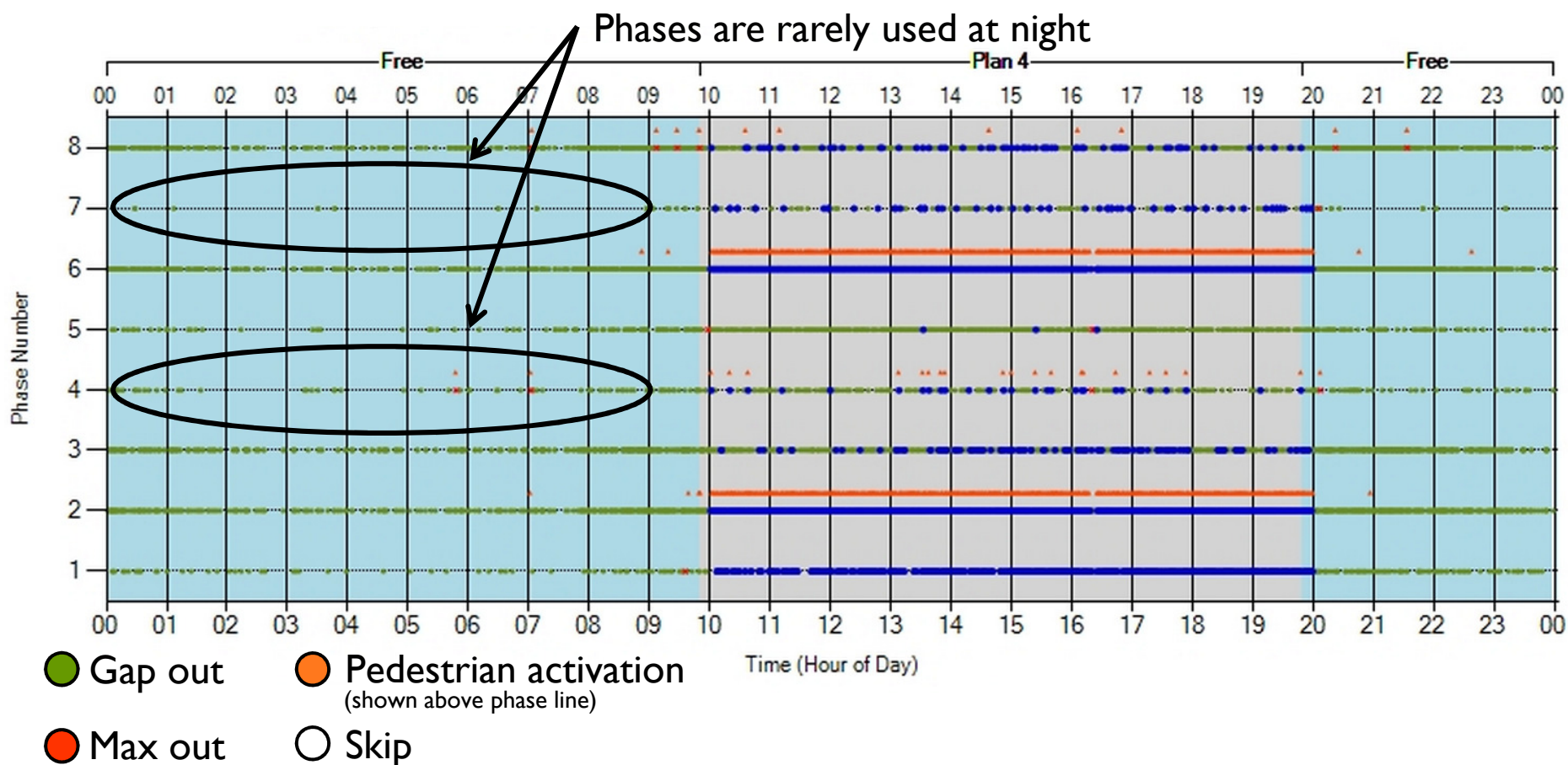


**Metric: Purdue Phase Termination  
 Detection Requirements: None**

# Complaint: Long red at 2 a.m., no other traffic

**After**

New detection technology installed



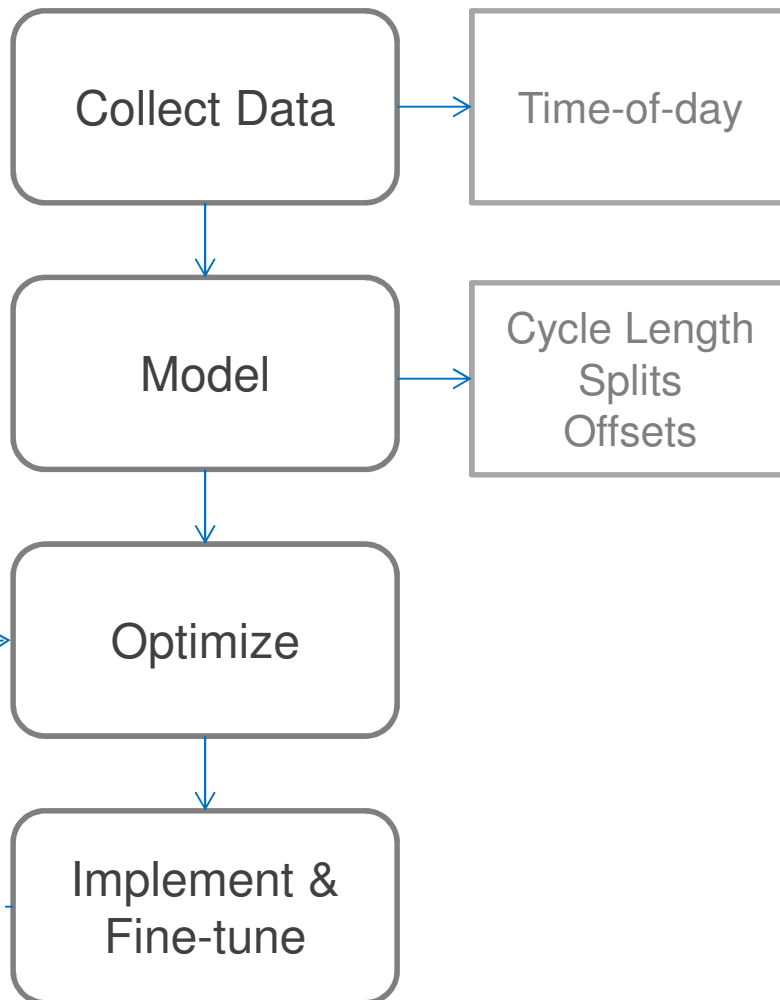
**Metric: Purdue Phase Termination**  
**Detection Requirements: None**



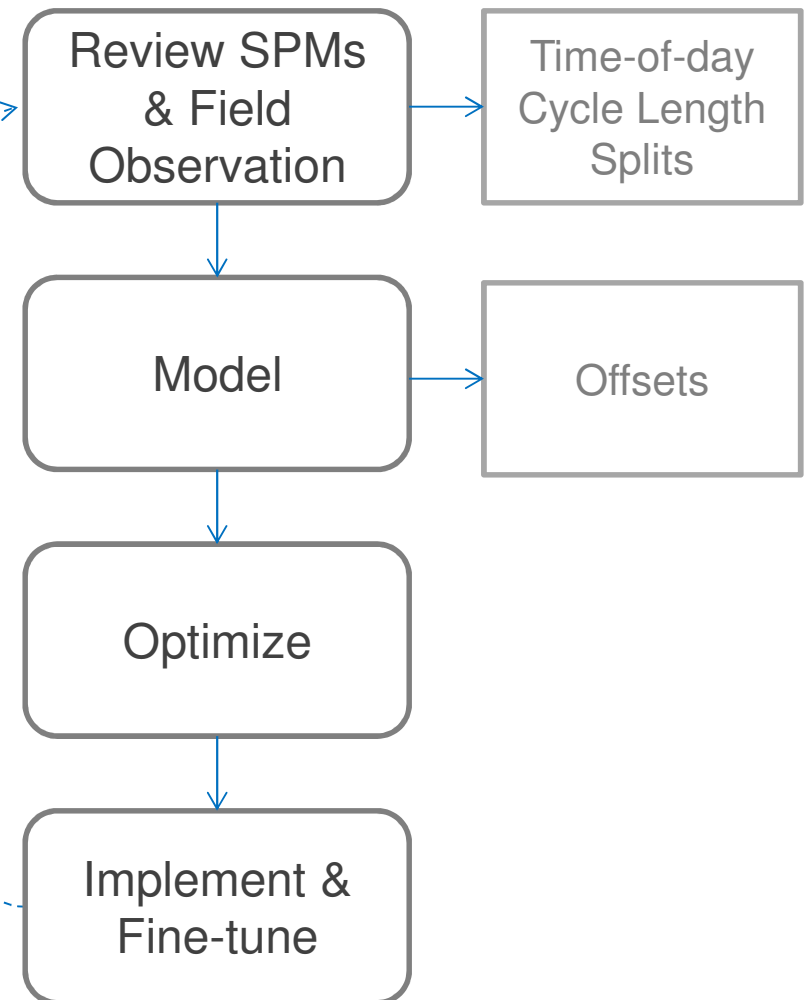
# Signal Optimization with SPMs

# Optimization with SPMs

## Traditional Process



## Modified Process with SPMs



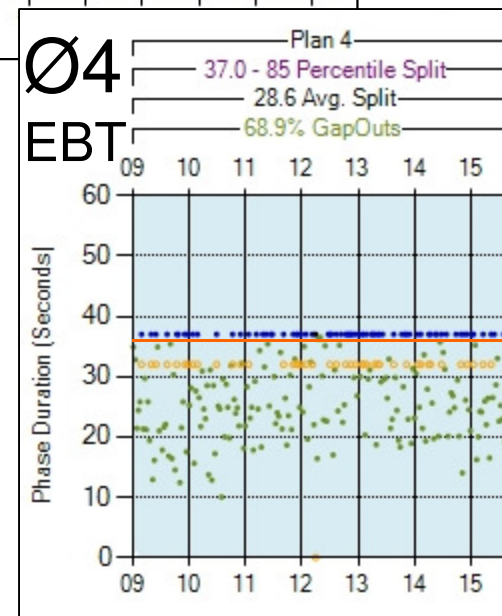
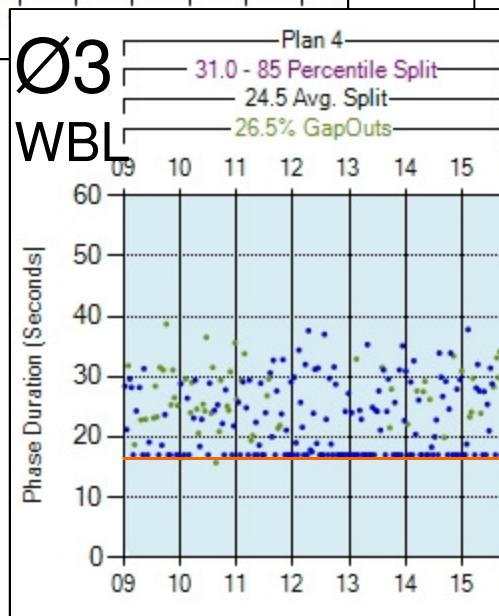
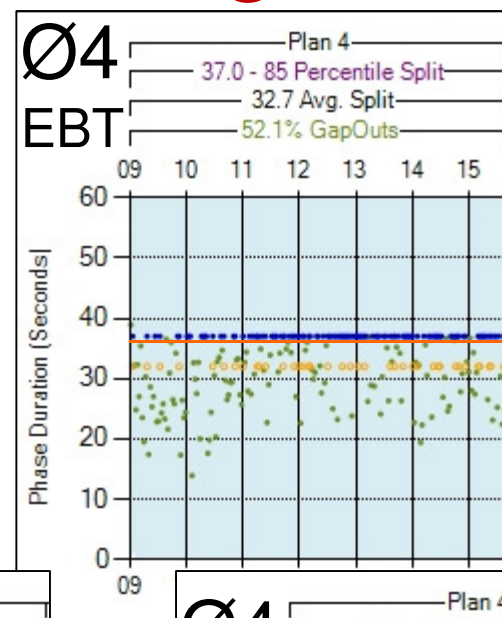
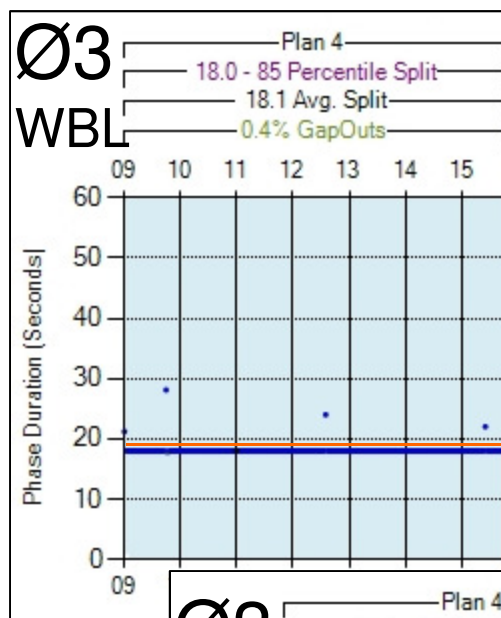
# Evaluate Impact of Timing Change

- Before:

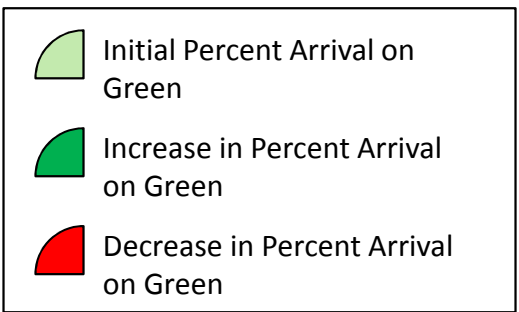
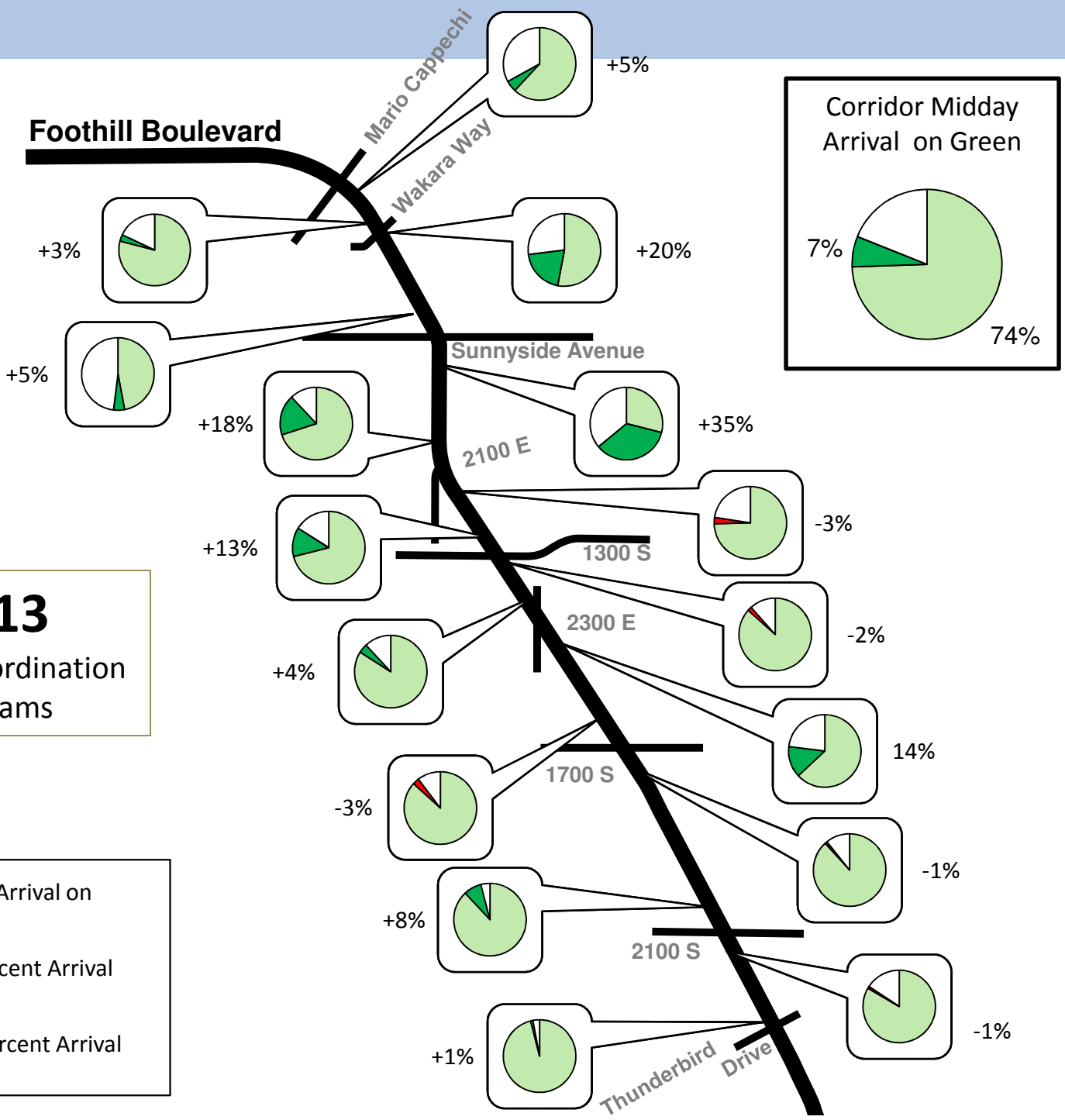
1 2 | 3 4  
 5 6 | 7 8

- After:

1 2 | 4 3  
 5 6 | 7 8



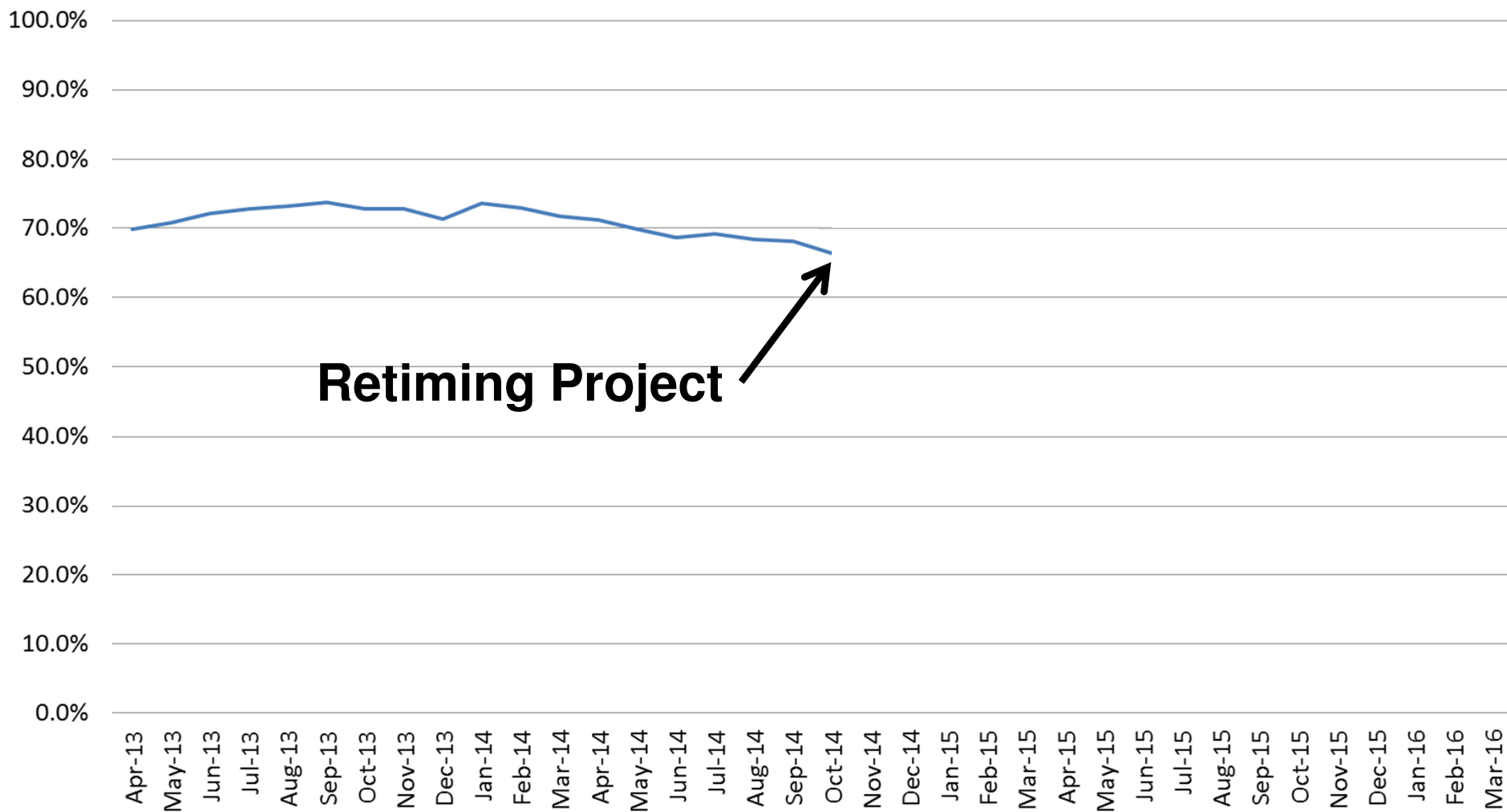
# Benefits Reporting



# Monitor Trends

## Percent of Vehicles Arriving on Green - **Riverdale Rd**

10:00 AM to 2:00 PM Monday through Friday

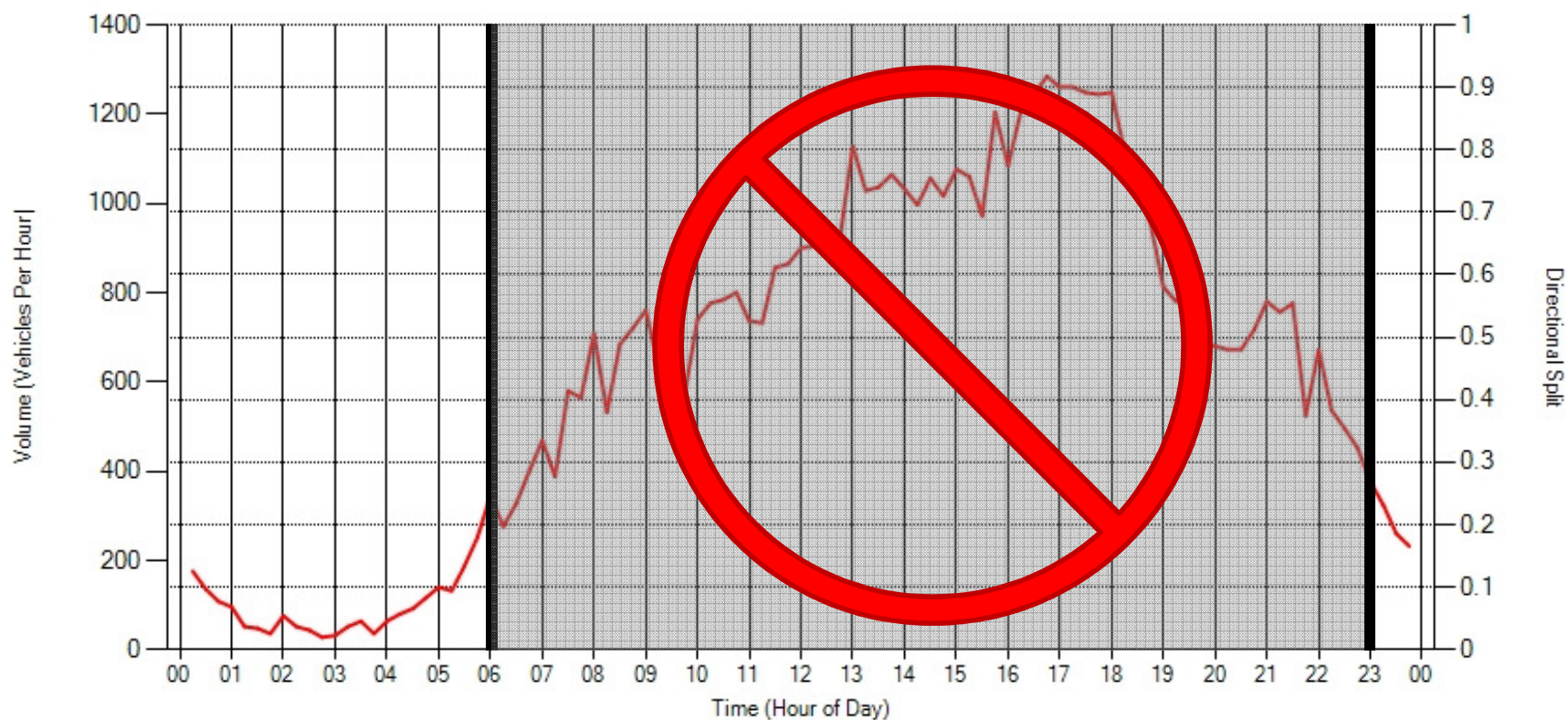




# SPM Use Beyond Signal Operations

# Allow Lane Closures

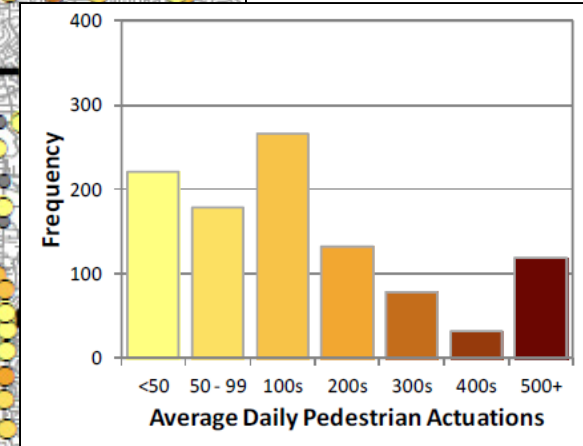
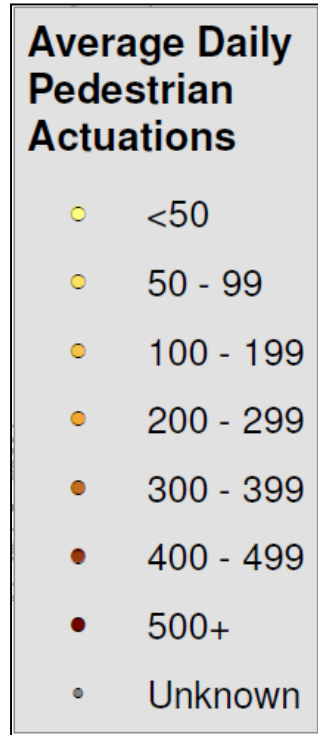
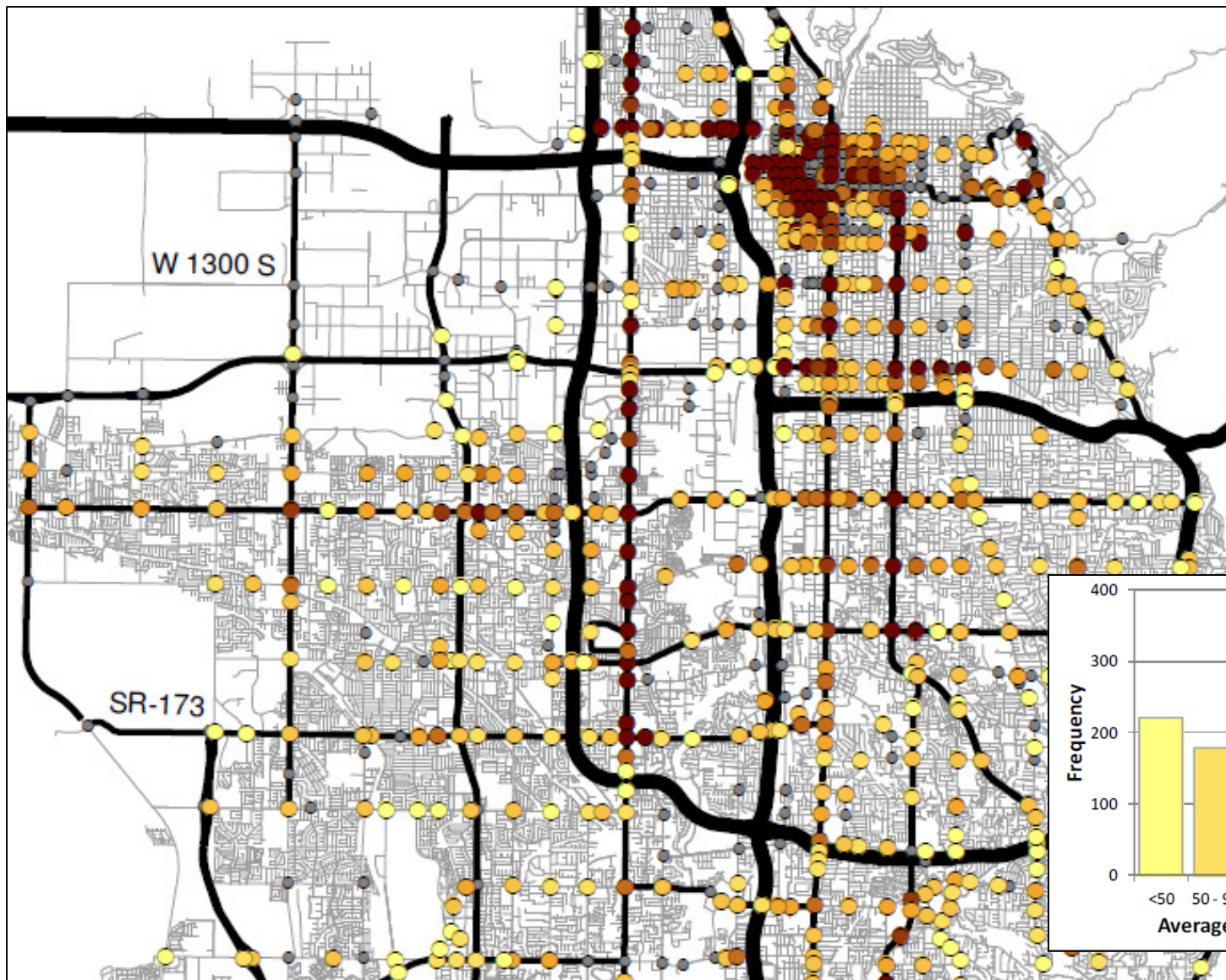
Volume report for University Avenue East Bay Boulevard on the Northbound and Southbound approaches.  
 7/7/2016 12:00:00 AM - 7/7/2016 11:59:00 PM - Using Advanced Detection









# Active Transportation



# http://udottraffic.utah.gov/signalperformancemetrics



## Signal Performance Metrics



Charts
Reports
Log Action Taken
Links
FAQ

[->Signal Metrics](#)

Selected Signal

Signals

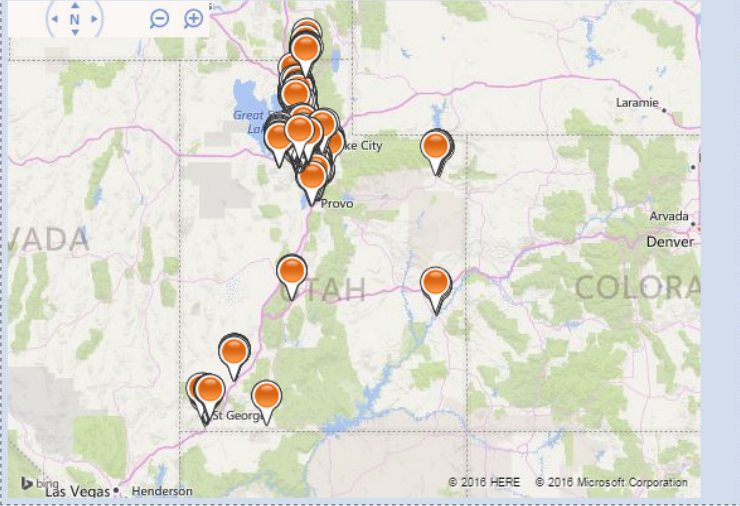
Region:

Metric Type:

Filter:

**Signal List**

**Map**



Metric Settings

Metric Type

- Approach Delay
- Approach Volume
- Arrivals On Red
- Purdue Coordination Diagram
- Purdue Split Failure
- Pedestrian Delay
- Preemption Details
- Purdue Phase Termination
- Speed
- Split Monitor
- Turning Movement Counts
- Yellow and Red Actuations

Time Y Axis Maximum:

Volume Y Axis Maximum:

Volume Bin Size:

Dot Size:

Show Plan Statistics

Show Volumes

[Export Data](#)

Upload Current Data

Dates

Start Date:

End Date:

Reset Date:

Sun	Mon	Tue	Wed	Thu	Fri	Sat
27	28	29	30	31	1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31	1	2	3	4	5	6



# 16 Agencies using SPMs



# SPM Source Code -> Open Source

## Nov. 2016

U.S. Department of Transportation  
Federal Highway Administration














OSADP

HOME INFORMATION **COMMUNITY** CONTACT LOGIN

Search ...

### Explore Applications

#### APPLICATION CATEGORIES


 All Active Releases	38
 Arterial Management	16
 Collision Avoidance	4
 Collision Notification	4
 Commercial Vehicle Operations	8
 Crash Prevention & Safety	8
 Driver Assistance	16
 Electronic Payment & Pricing	0
 Emergency Management	6
 Freeway Management	15
 Information Management	20
 Intermodal Freight	7
 Road Weather Management	4

Sort by Name

Filter Applications

Show 5 Items

<< First < Previous Next > Last >>




**CV-DSRC-Msg-Parser 1.1** STABLE

*Connect Vehicles - Dedicated Short-Range Communications*

Version: CV-DSRC-MsgParser 1.1  
Modified: Mar 31, 2016  
Downloads: 50

Keywords: [bsm](#) [dsrc](#) [parsing](#) [analysis](#) [data](#)




**CVD-DME 1.0** STABLE

*Connected Vehicle Data-Driven Measures Estimation*

Version: CVD-DME 1.0  
Modified: Aug 22, 2016  
Downloads: 59

Keywords: [connected vehicles](#) [data](#) [trajectory converter](#) [analysis](#)



**DIRECTView-AMS-v1.0** STABLE

*Dynamic Intermodal Routing Environment for Control and Telematics - Analysis, Modeling and Simulation*

Version: DIRECTView-AMS-v1.0  
Modified: Sep 1, 2016



# Salt Lake SPM Workshop Participants – Jan 2016

-  20 State & Federal Agencies
-  25 Public Agencies
-  5 Universities
-  35 Private Sector Locations



***170 Representatives from 85 Different Organizations, 28 States, DC, & Canada***

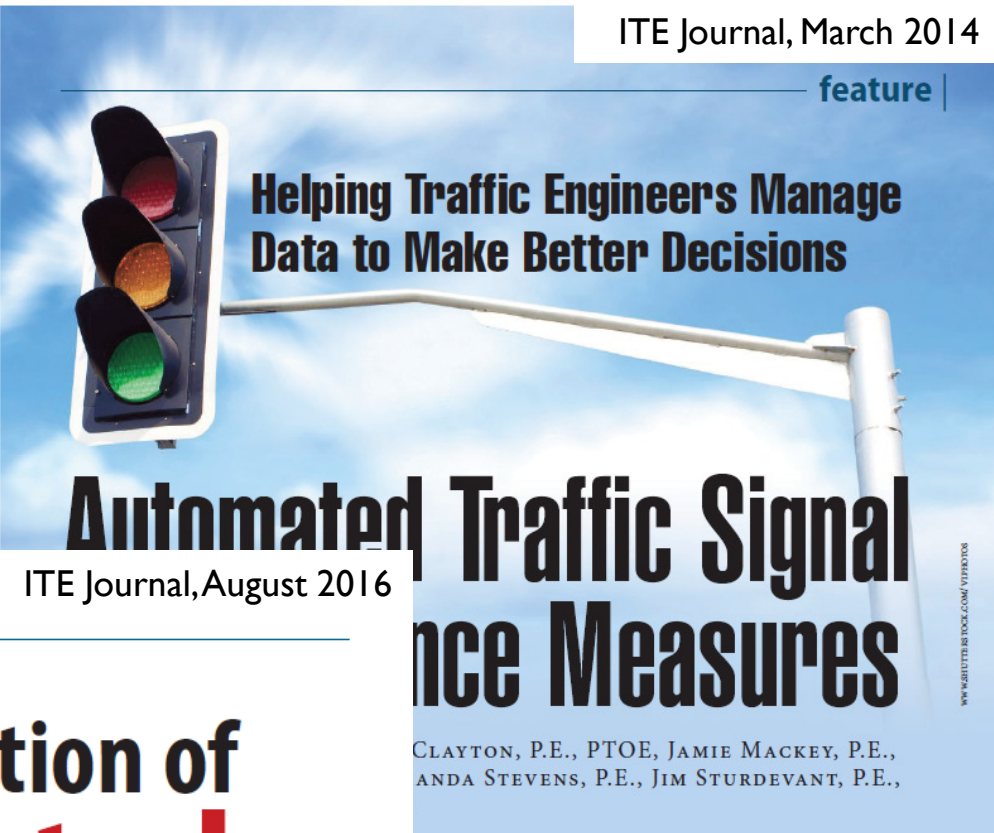
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Institute of Transportation Engineers

ITE 3-part Webinar  
April, May, June 2014

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**Automated Traffic Signal Performance Measures**



**Helping Traffic Engineers Manage Data to Make Better Decisions**

**Automated Traffic Signal Performance Measures**

ITE Journal, August 2016

CLAYTON, P.E., PTOE, JAMIE MACKAY, P.E., ANDA STEVENS, P.E., JIM STURDEVANT, P.E.,

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# Implementation of **Automated Traffic Signal Performance Measures**

BY CHRISTOPHER M. DAY, PH.D., MARK TAYLOR, P.E., PTOE,  
JAMIE MACKAY, P.E., PTOE, ROB CLAYTON, P.E., PTOE,  
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JAMES R. STURDEVANT, P.E., AND DARCY BULLOCK, P.E.

Smooth and equitable traffic flow are goals for most limited snapshot-view retiming methods that involve signal modeling, and field fine-tuning are resource changes in traffic patterns. The National Transportation Traffic Signal Report Card has led agencies to focus on methodologies to examine all the components of traffic program management plans provide objective methods encourages coordination with neighboring jurisdictions. In large activities when resources are constrained.



# AASHTO

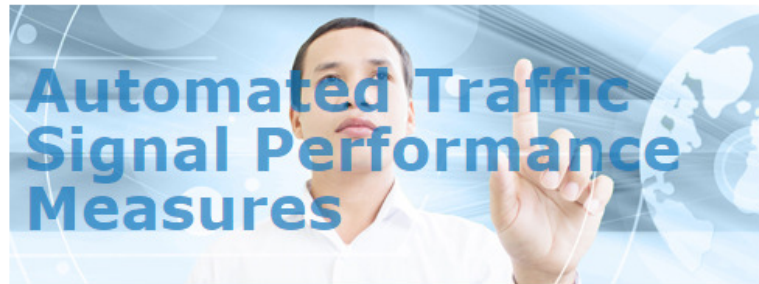
AASHTO INNOVATION INITIATIVE

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## Automated Traffic Signal Performance Measures

AASHTO > AASHTO Innovation Initiative > Automated Traffic Signal Performance Measures



### What are Automated Traffic SPMs

Automated signal performance metrics show real-time and historical functionality at signalized intersections. This allows... [More >>](#)

[Implementation](#)

[Hand-Outs](#)

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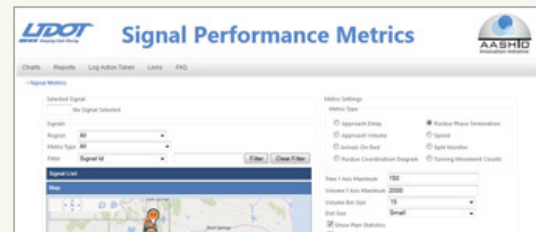
[Contacts](#)

## Implementation

The software developed by UDOT has been shared freely with multiple agencies and companies around the country. Several cities and DOTs, including a few in Canada, have shown interest in it. Currently, five locations are using SPMs and at least four are in the process of implementing the system.

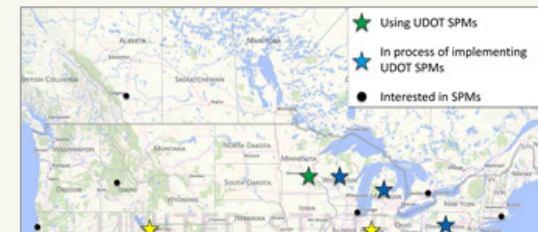
### SIGNAL PERFORMANCE METRICS IN UTAH

To see how SPMs work, visit [UDOT's live website](#).



### SPMs USAGE/INTEREST MAP

Map of SPMs system usage and interest.





# every day counts

An Innovation Partnership with States



Mobility • Safety • Quality • Environment • Shortening Project Delivery

## EDC-4 Innovations (2017-2018)

### Automated Traffic Signal Performance Measures (ATSPMs)

Highway agencies typically rely on complaints or manual data collection to identify the need for signal retiming projects and their outcomes. These projects are typically scheduled on a 3- to 5-year cycle, at a cost of approximately \$4,500 per intersection. The costs and effort associated with collecting performance data translates into congestion, reduced safety, and increased delays for vehicles, pedestrians, and bicyclists.

That's where automated traffic signal performance measures come in. They will revolutionize the management of traffic signals by providing the high-resolution data needed to actively manage performance. High-quality service can be delivered to customers with significant cost savings to agency maintenance and operations. A number of implementation options are available, ranging from a low-cost, open-source code framework to a fully integrated traffic signal system.

### Collaborative Hydraulics: Advancing to the Next Generation of Engineering (CHANGE)

Current modeling techniques used for hydraulic design apply several assumptions that can lead to overly conservative or inaccurate results. Advanced hydraulic modeling technologies

### Contact

[View list of EDC-4 contacts.](#)

### EDC-4 Summits

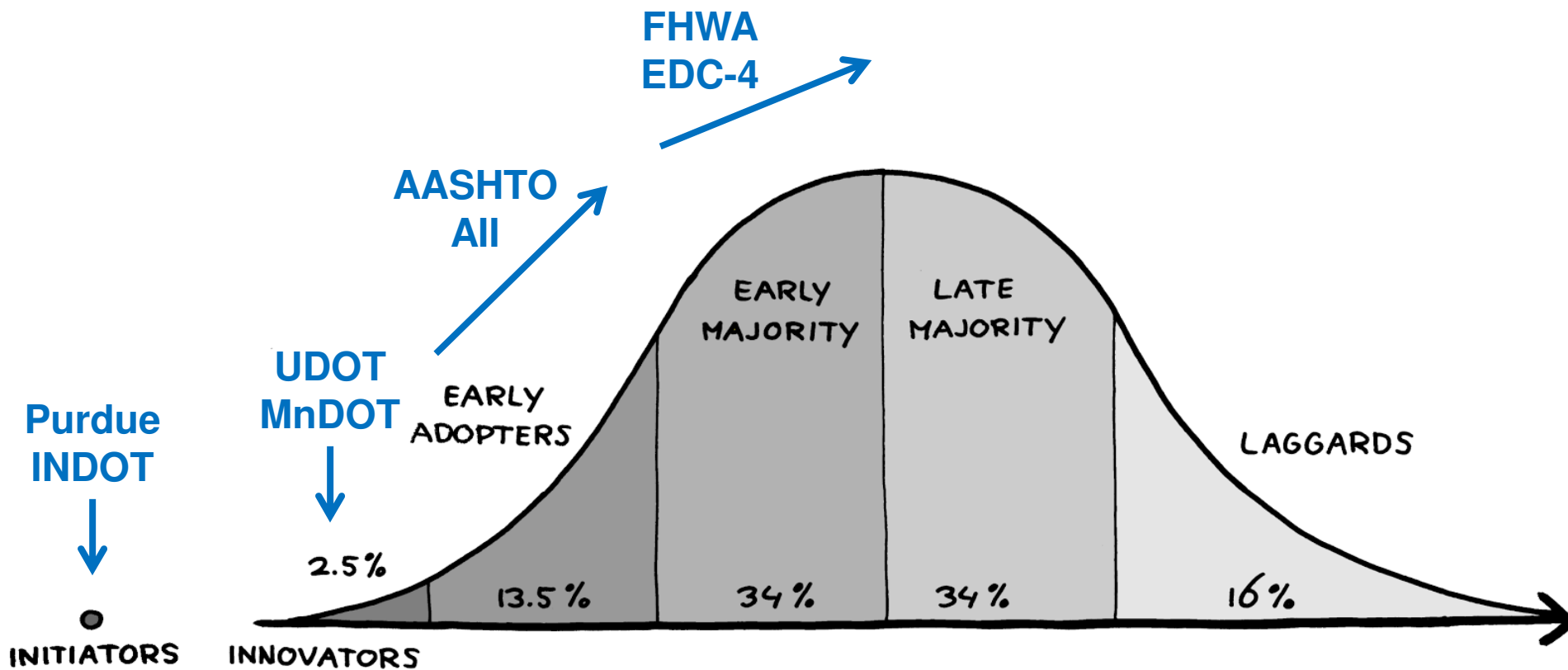
[View EDC-4 Regional Summit information](#)

[View EDC-4 webinars](#)

[EDC-4 Generic Summit Agenda](#)

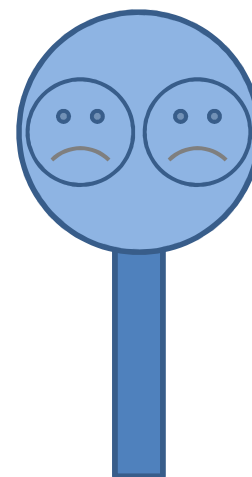
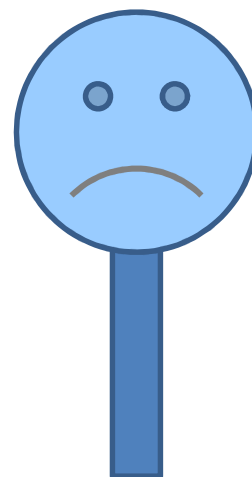
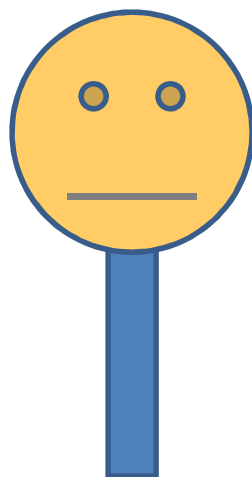
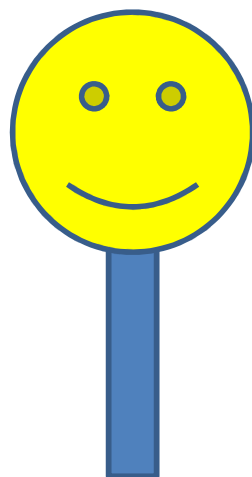
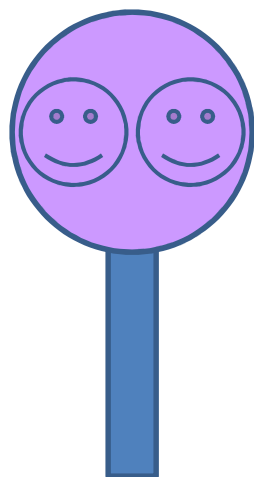
### EDC Rounds

# Innovation/Adoption Curve



# UDOT Signal Timing Focus Group (July 2014)

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

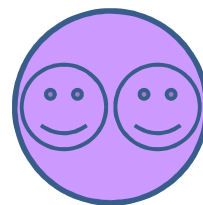
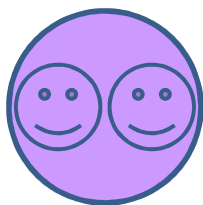
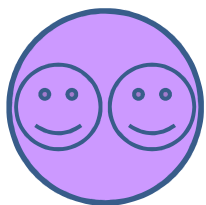


## Focus Group Key Findings (July 2014)

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>





# Alert Evaluation

**1** No SPM Data

- Check communication to signal
- Check controller clock
- Check IP address in SPM configuration
- Check VOIT Trace Enabled & Saving-wait
- 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

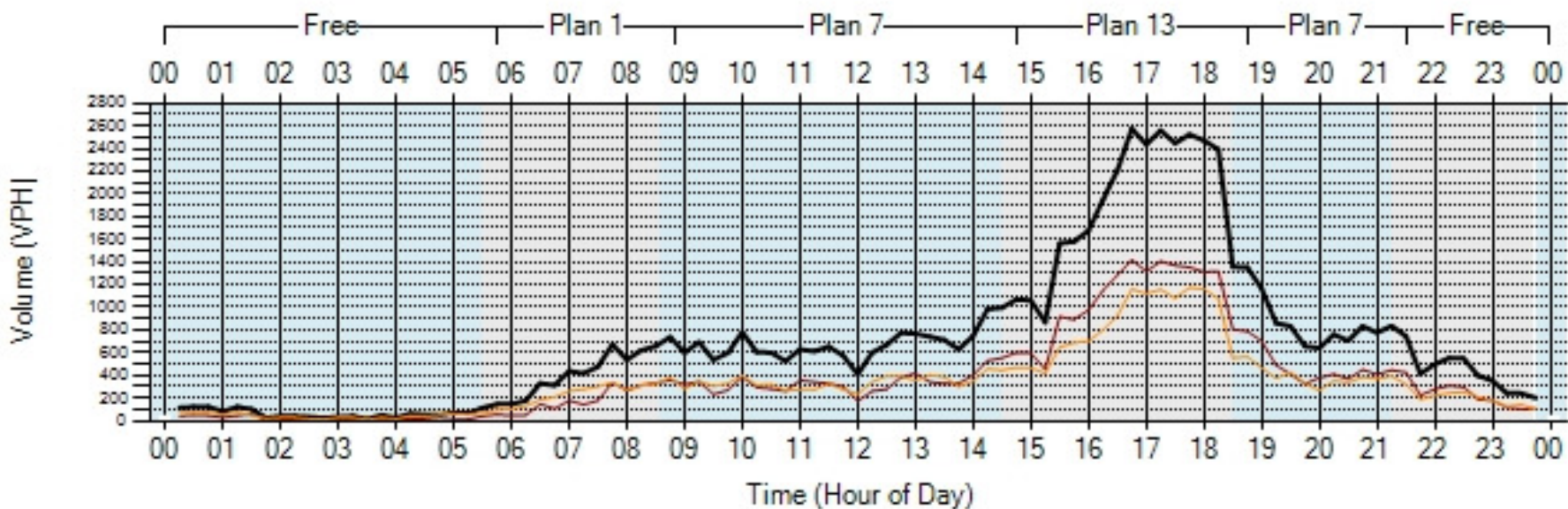
- Note: Evaluate the VOLUME on the PCD charts, not the phase data*
- Is count channel configured correctly in SPM Config Tool?
- Is ECPI Log enabled for count channel?
- Is the detector working?
- Is the detector communicating to the controller?
- Try resetting the sensor and VERIFY with Upload Current

# Determine Approach Capacity

US-89 Nicholls Rd SIG#5208  
 Wednesday, May 11, 2016 12:00 AM - Wednesday, May 11, 2016 11:59 PM

## Northbound Thru

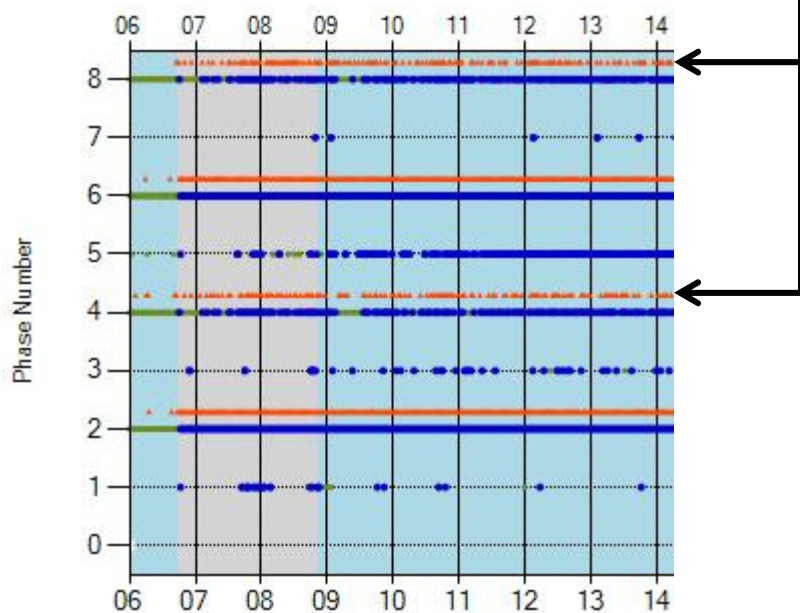
TV: 16693 PH: 4:45 PM - 5:45 PM PHV: 2505 VPH  
 PHF: 0.97 fLU: 0.95



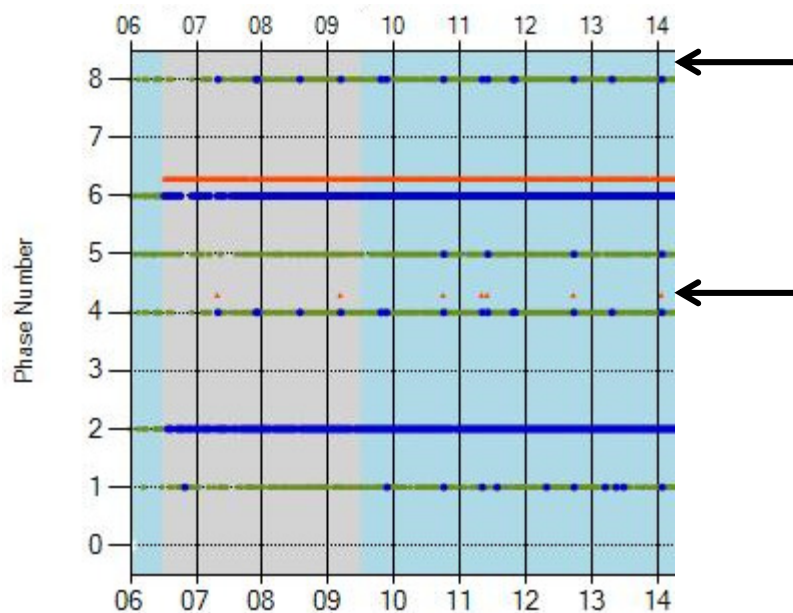
— Total Volume — Lane 1 — Lane 2

# “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



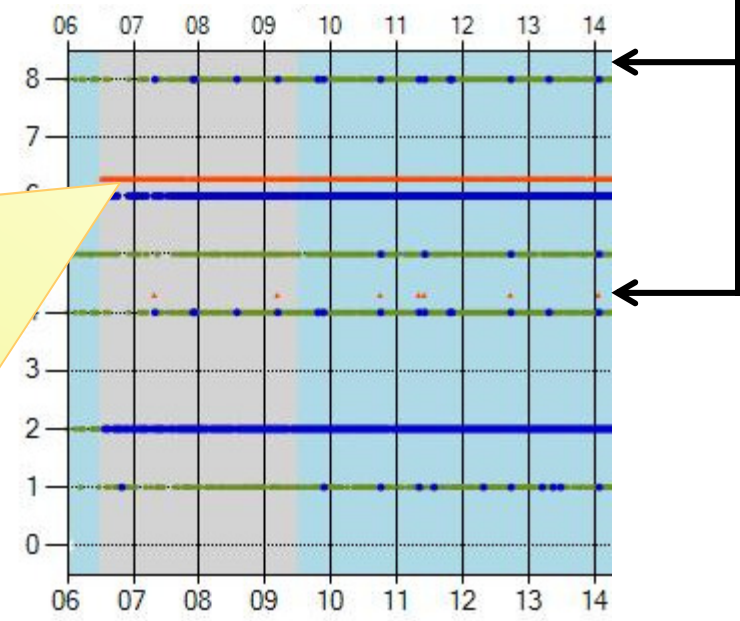
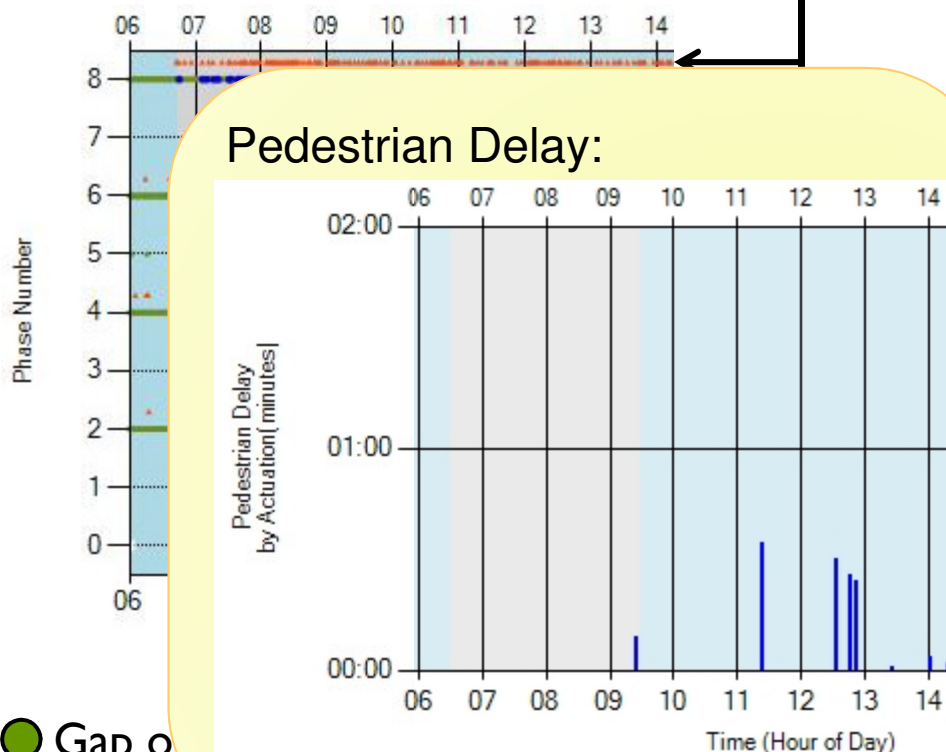
- Gap out
- Pedestrian activation (shown above phase line)
- Max out
- Skip
- Force off

**Metric: Purdue Phase Termination**  
**Detection Requirements: None**

# “Can we oversize the peds?”

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- Gap out
- Max out
- Force off

**Metric: Purdue Phase Termination**  
**Detection Requirements: None**