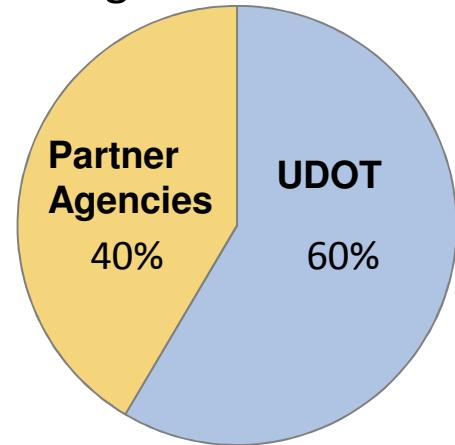


# UDOT Automated Traffic Signal Performance Measures (ATSPMs)

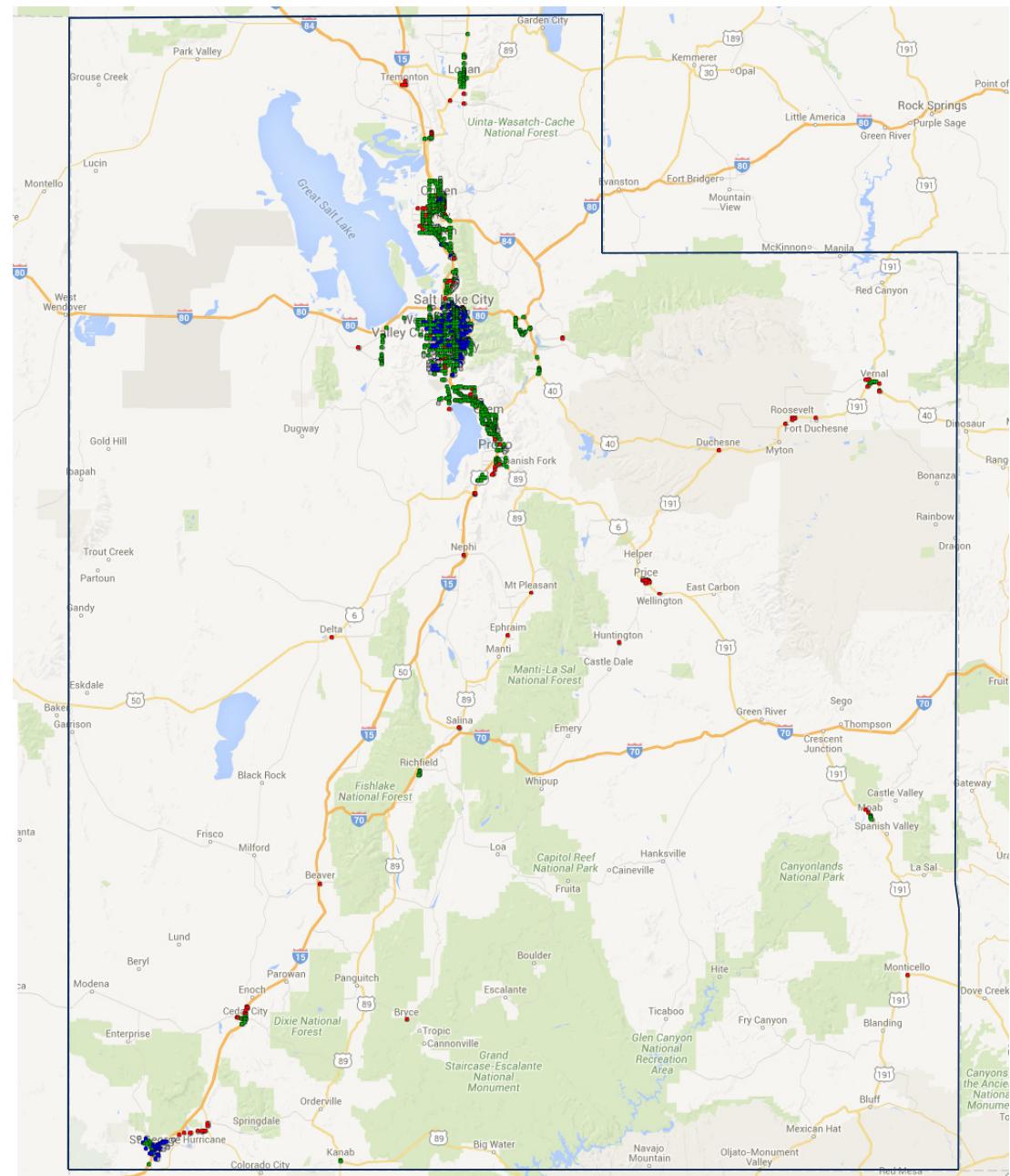
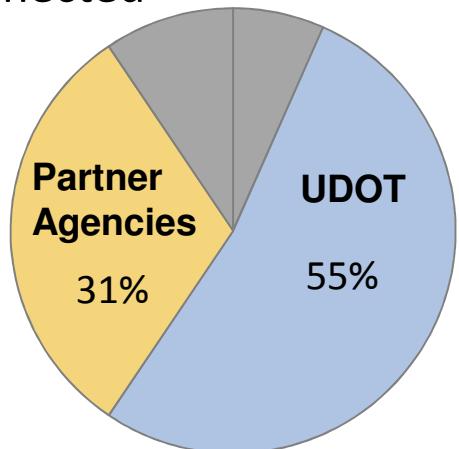
Jamie Mackey  
UDOT Statewide Signal Engineer  
[jamiemackey@utah.gov](mailto:jamiemackey@utah.gov)

# 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

WORLD CLASS  
TRAFFIC SIGNAL MAINTENANCE  
& OPERATIONS



QUALITY IMPROVEMENT TEAM  
Final Report

July 2011

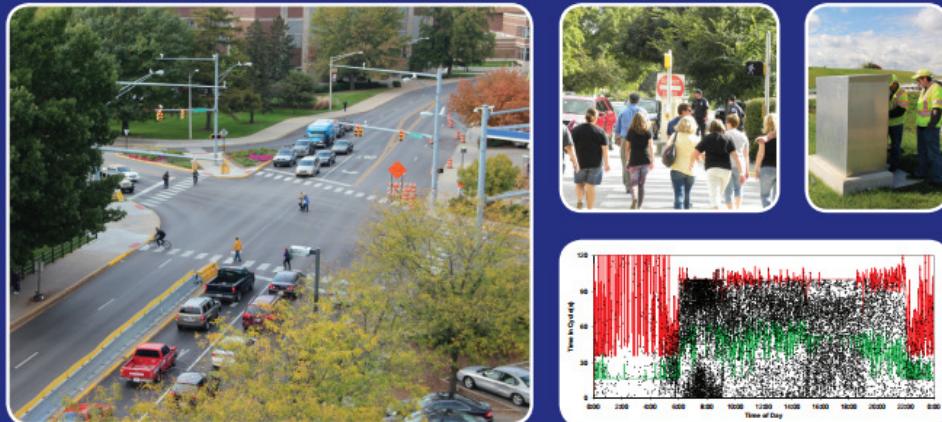


**PURDUE**  
UNIVERSITY



# PERFORMANCE MEASURES FOR TRAFFIC SIGNAL SYSTEMS

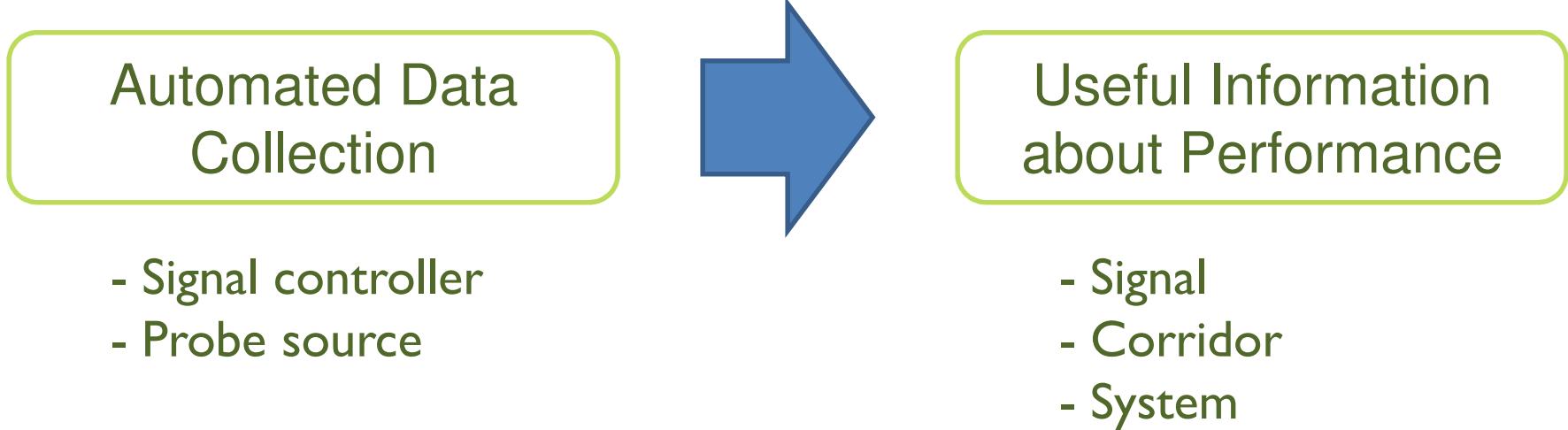
*An Outcome-Oriented Approach*



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



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

## 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

## 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

# Standard Control

## 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

JTRP Data Papers

11-2012

## Indiana Traffic Signal Hi Resolution Data Logger Enumerations

James R. Sturdevant

INDOT, [jsturdevant@indot.in.gov](mailto:jsturdevant@indot.in.gov)

Timothy Overman

INDOT

Eric Raamot

Econolite Group Inc.

Ray Deer

Peek Traffic Corporation

Dave Miller

Siemens Industry, Inc.

*See next page for additional authors*

Follow this and additional works at: <http://docs.lib.purdue.edu/jtrpdata>

 Part of the [Civil Engineering Commons](#)

### 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/K4RN35SH>.

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
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
6/27/2013 1:30:08.1	1	8
6/27/2013 1:30:13.1	32	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

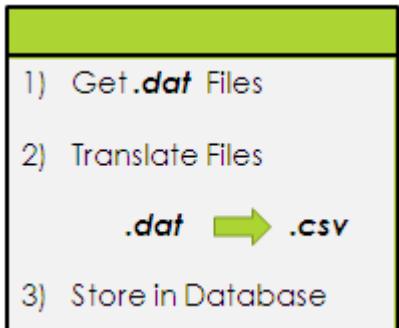
# System Requirements



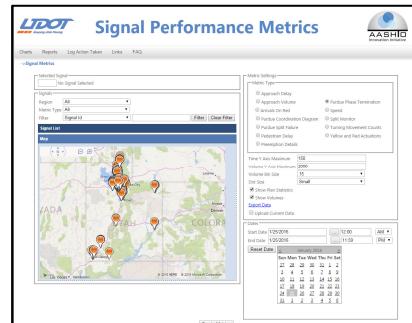
## High-resolution Controller



## Communications



## Server



## Software



## Detection (optional)

Photo courtesy of the Indiana Department of Transportation

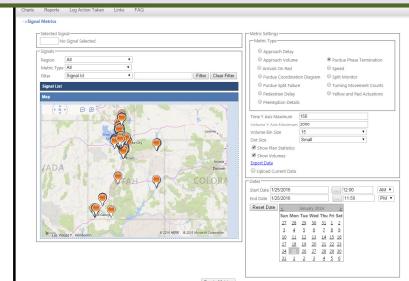
# System Requirements



Does NOT require  
Central Traffic Signal  
Management Software!

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

**Server**



**Software**

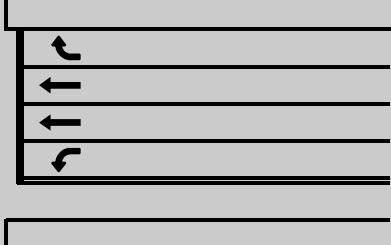
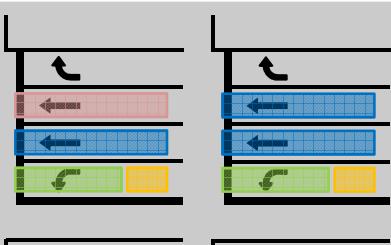


**Detection**  
(optional)

# 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

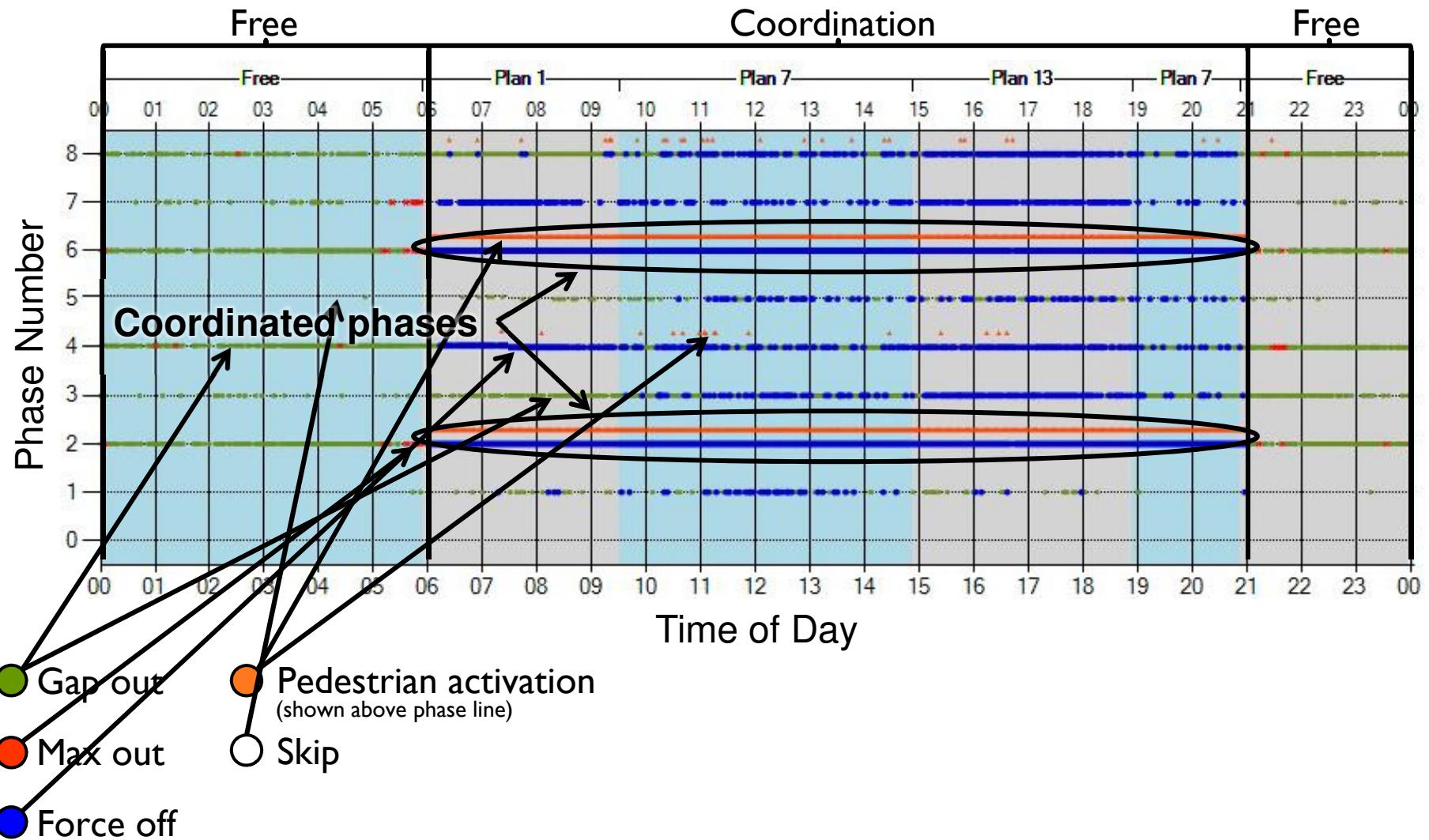
None



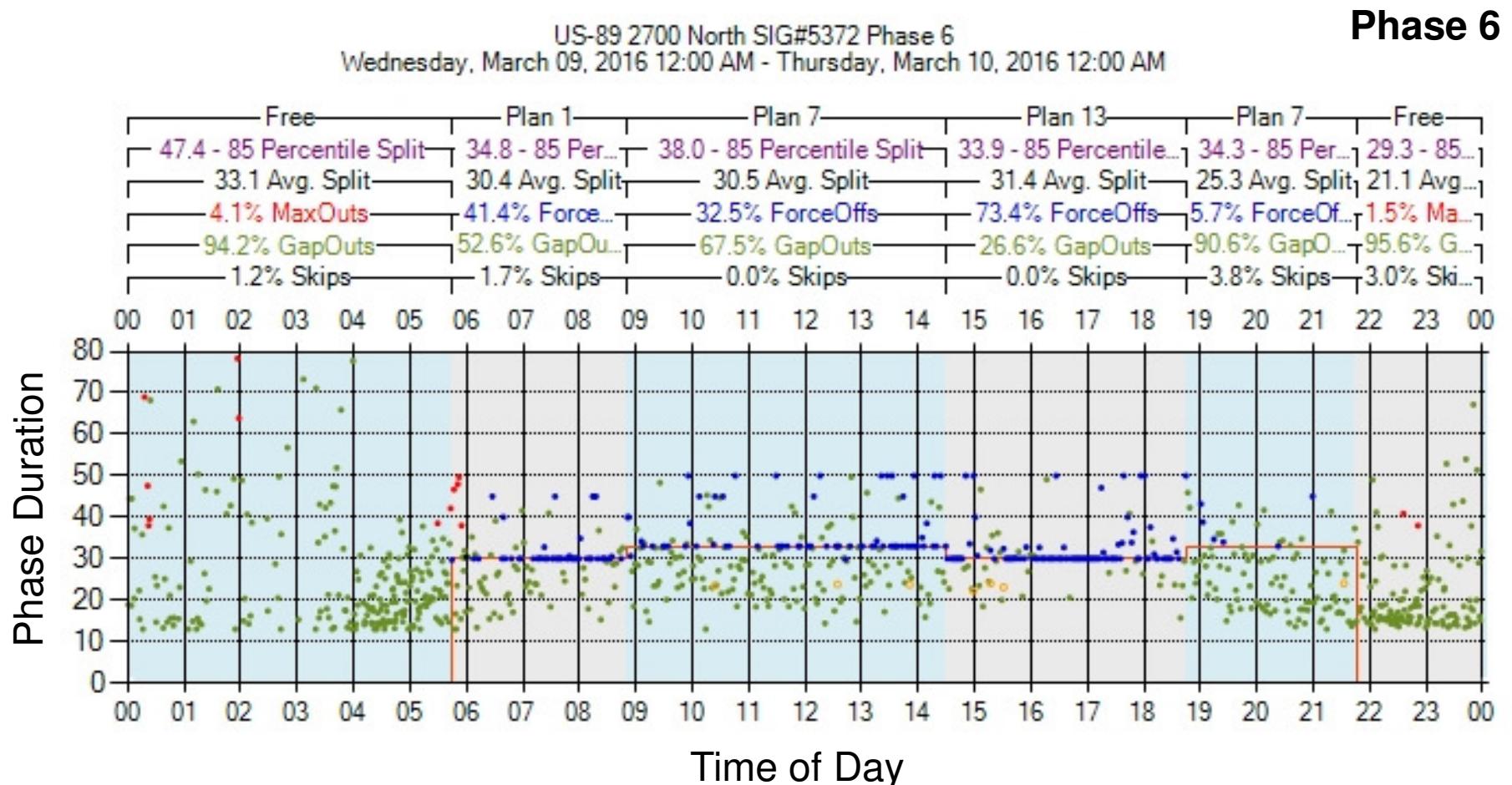
## Available Metrics

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

# Metric: Phase Termination Chart



# Metric: Split Monitor



## Detection

Setback Count Zones

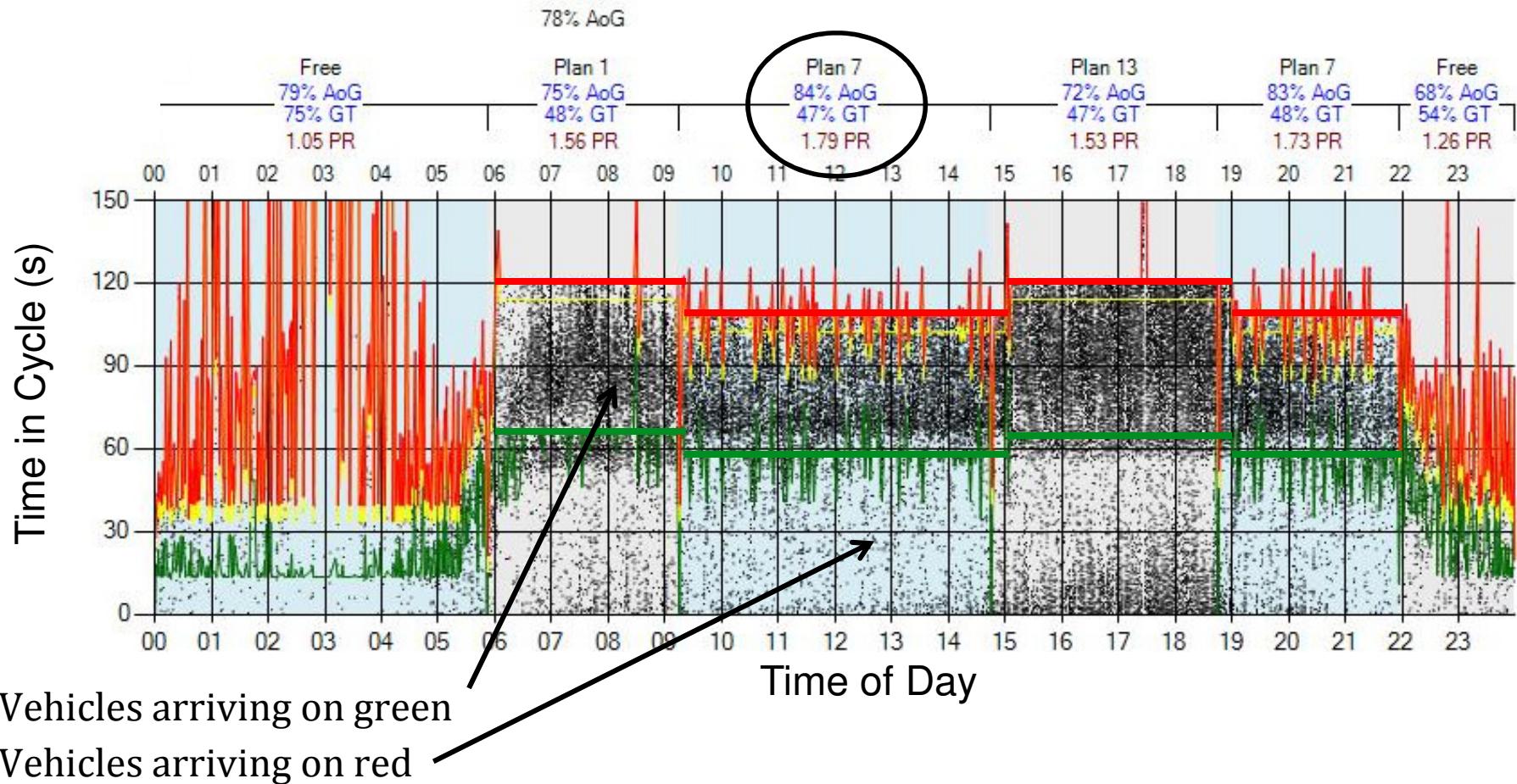


## Available Metrics

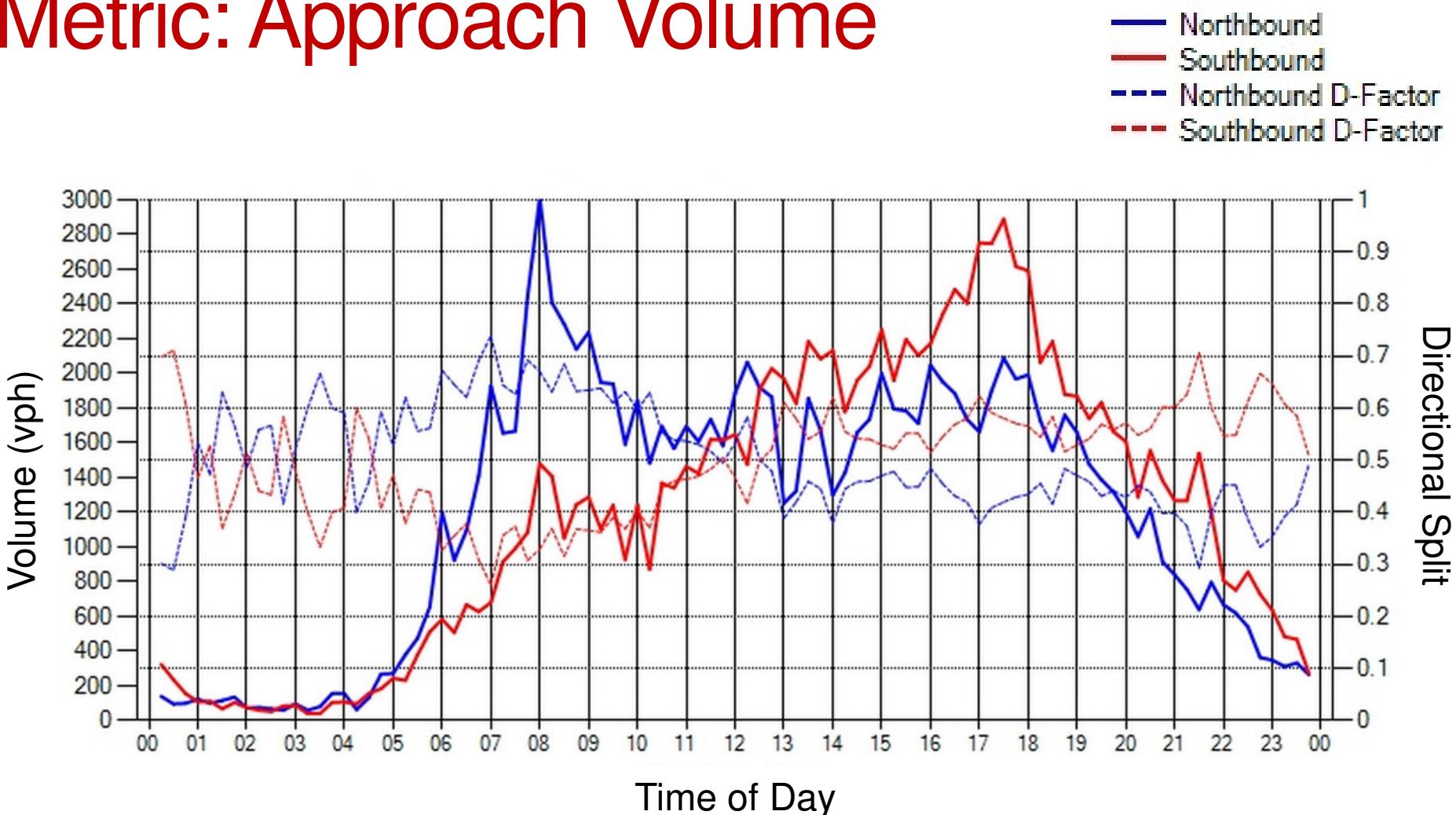
- ❯ Purdue Coordination Diagram
- ❯ Approach Volume
- ❯ Arrivals on Red
- ❯ Approach Delay

# 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



# Metric: Approach Volume



## Detection

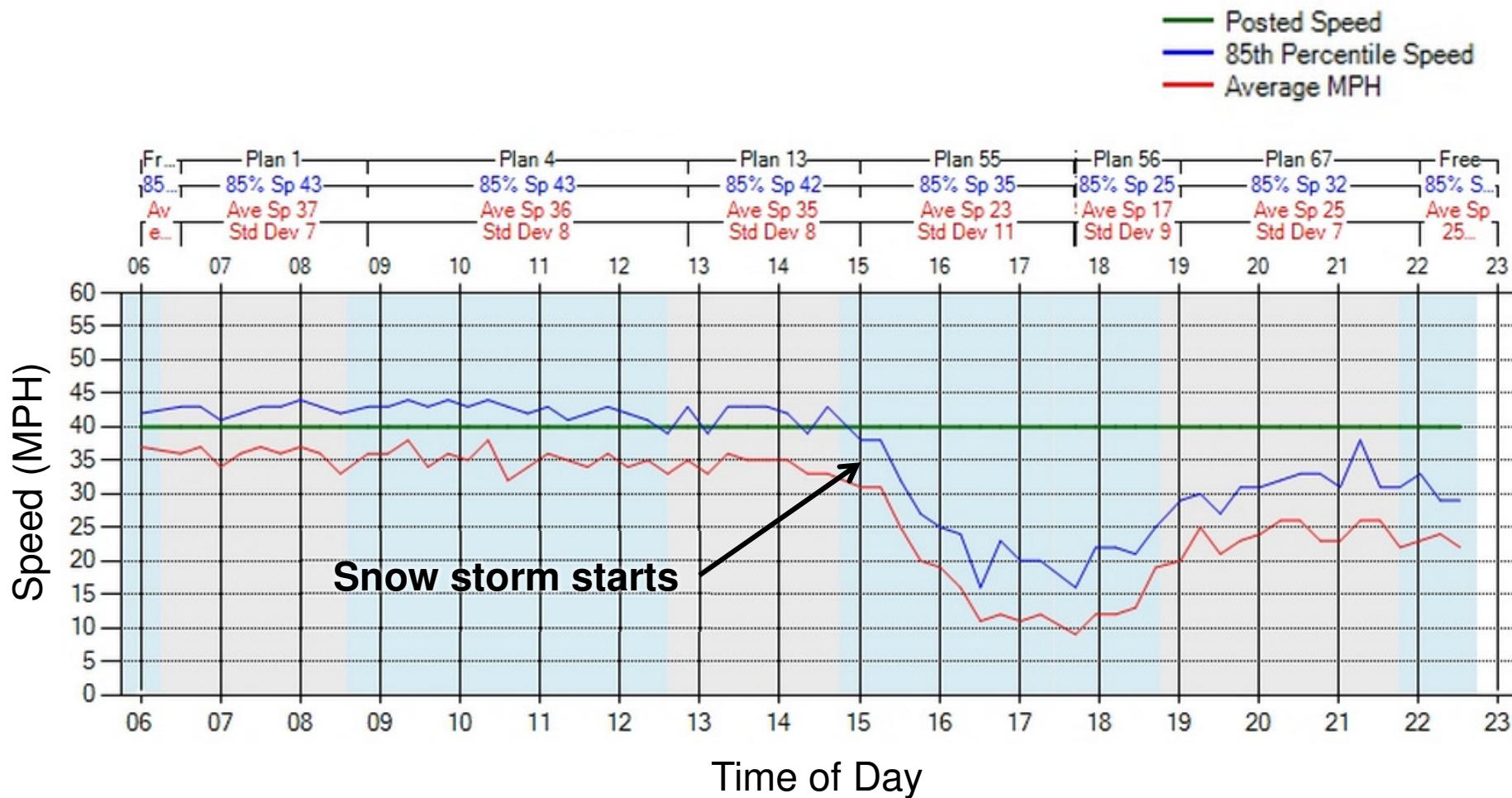
Setback Count Zones  
with speed

## Available Metrics

Approach Speed



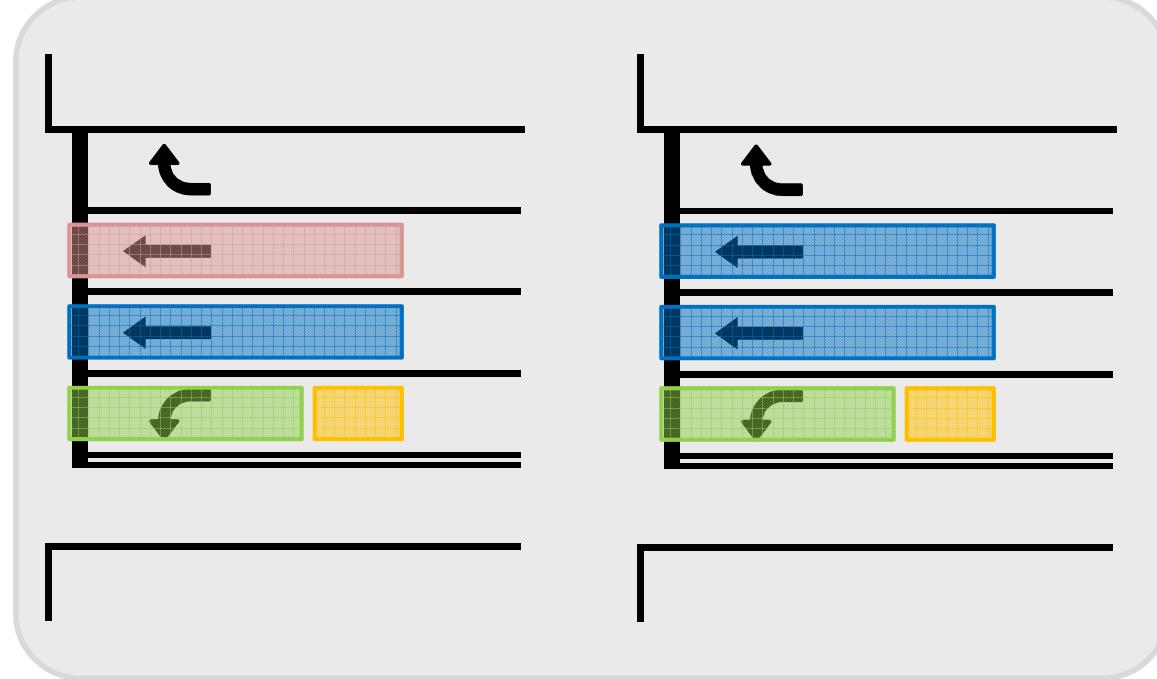
# Metric: Approach Speed



## Detection

Lane-by-lane Presence

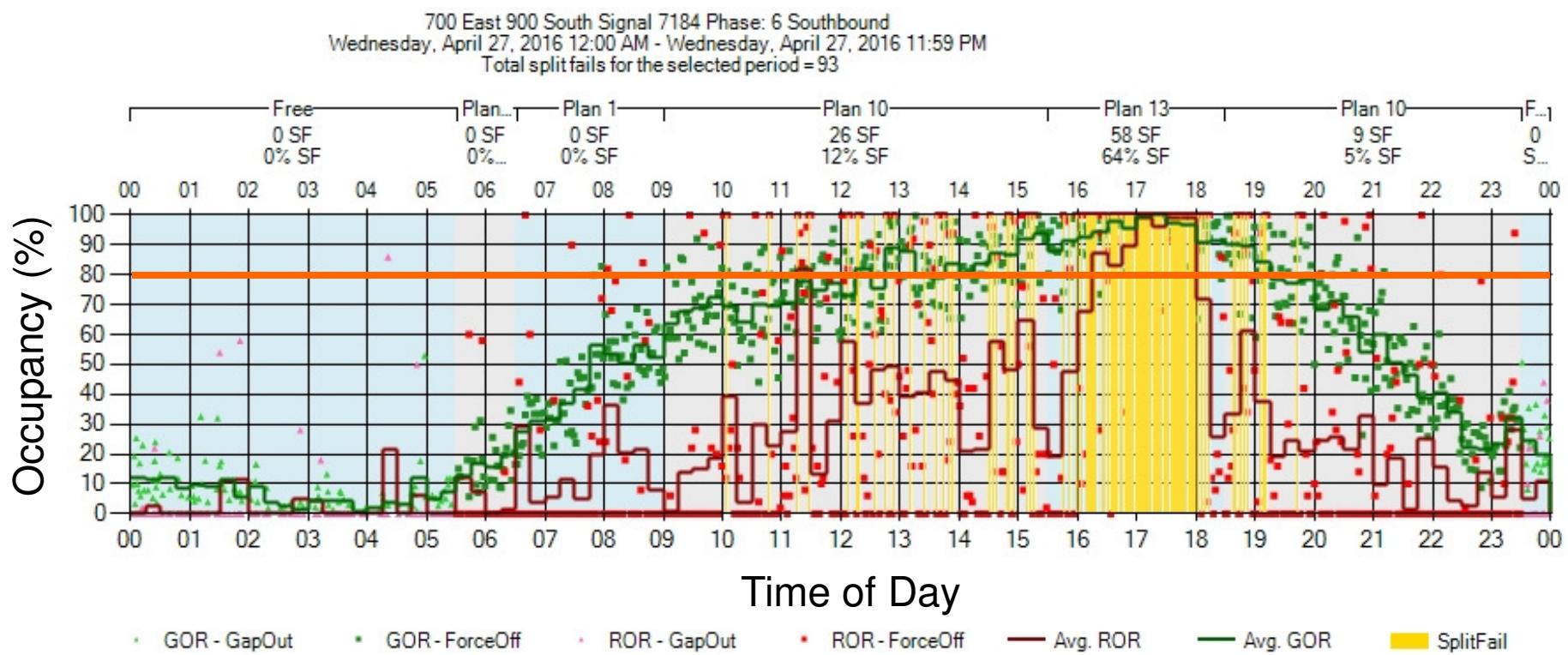
Lane Group Presence



## Available Metrics

➤ Purdue Split Failure

# Metric: Purdue Split Failure



## Detection

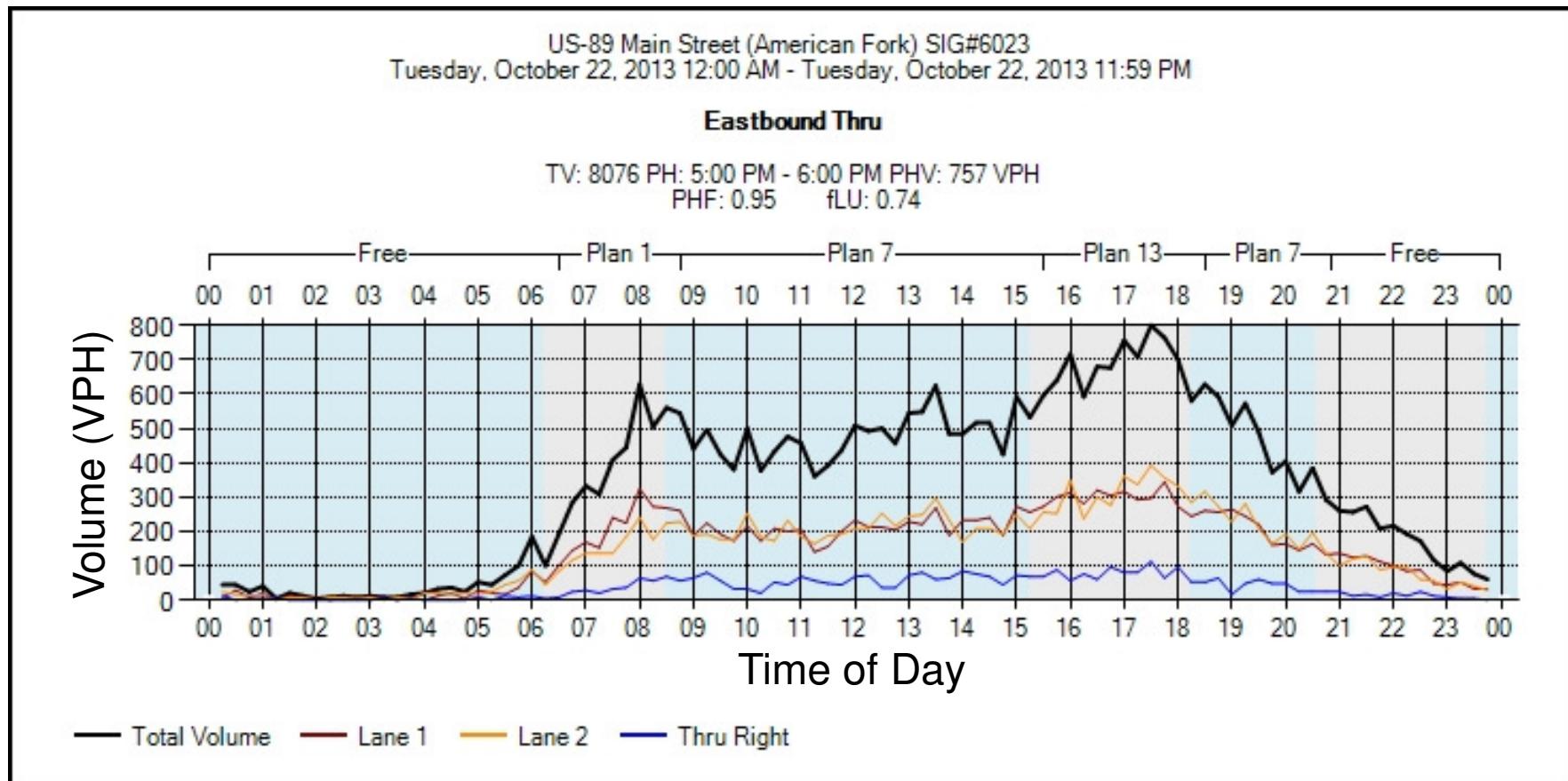
Lane-by-lane Count



## 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, i

–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%)

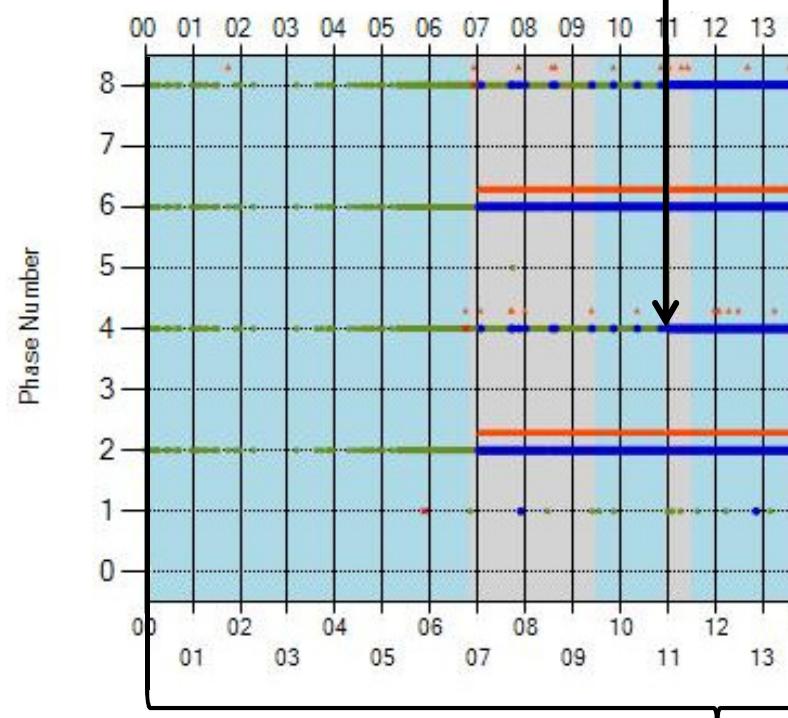
–The following signals had too many max out occurrences:  
1123 - Wolcott St & 100 South - Phase: 2 (Max Outs 100%)  
1124 - Sunnyside (850 S) & Guardsman Way - Phase: 2 (Max Outs 100%)  
1124 - Sunnyside (850 S) & Guardsman Way - Phase: 6 (Max Outs 100%)  
4024 - 7000 South (Fort Union) & 1300 East - 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

Phase 4 starts  
constant call



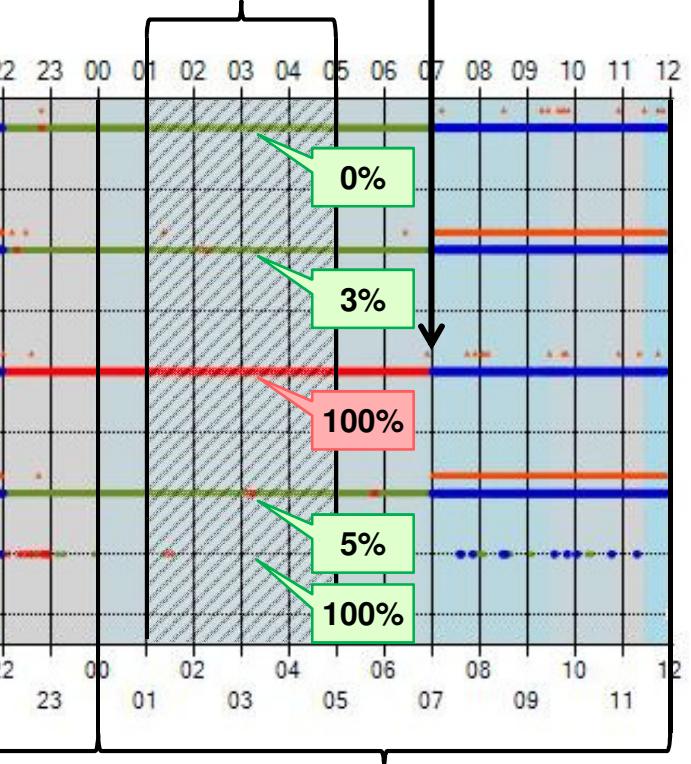
4/8/2014

- Gap out
- Max out
- Force off

- Pedestrian activation (shown above phase line)
- Skip

Alert email  
sent

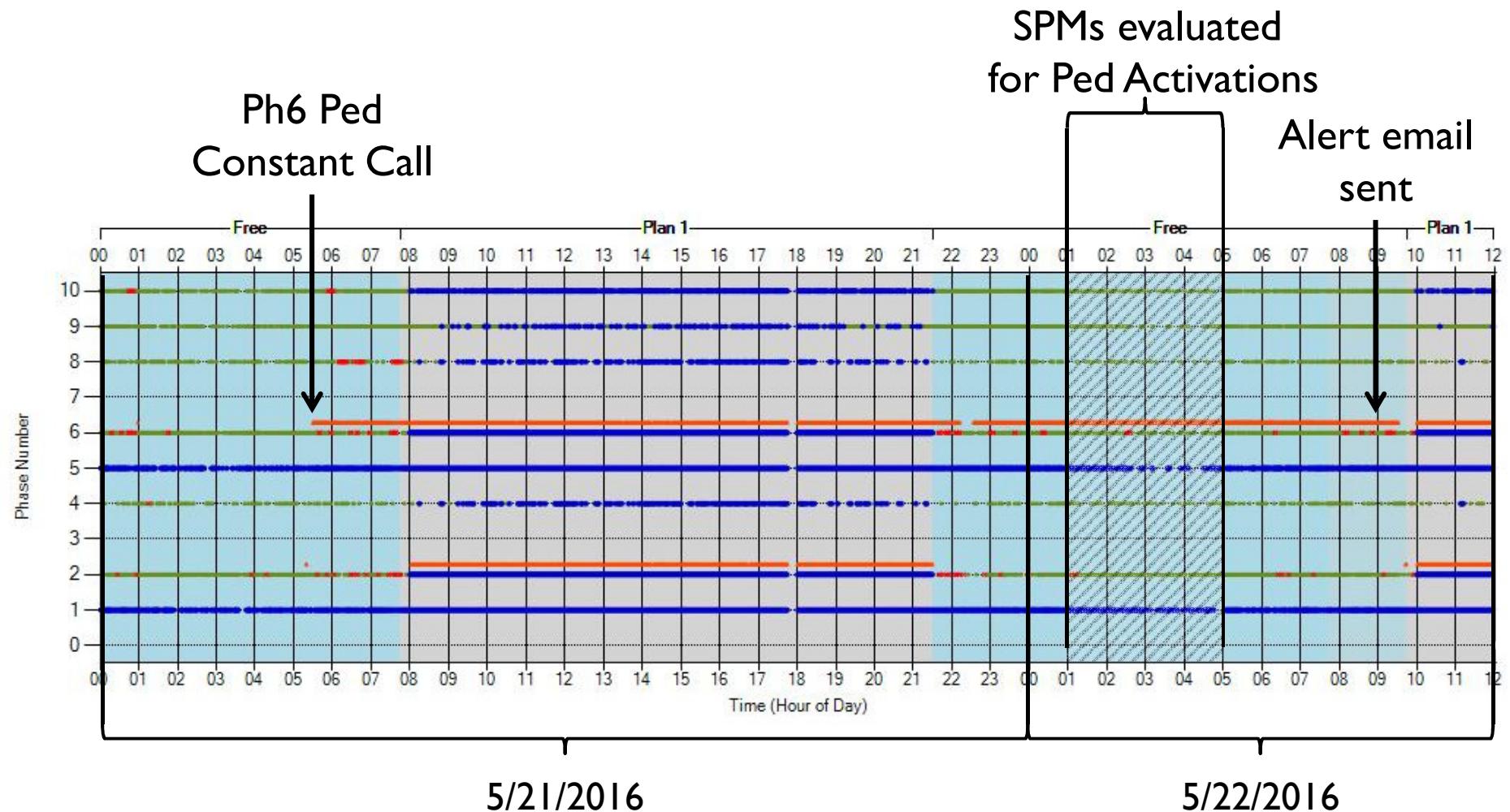
SPMs evaluated  
for % max outs



4/9/2014

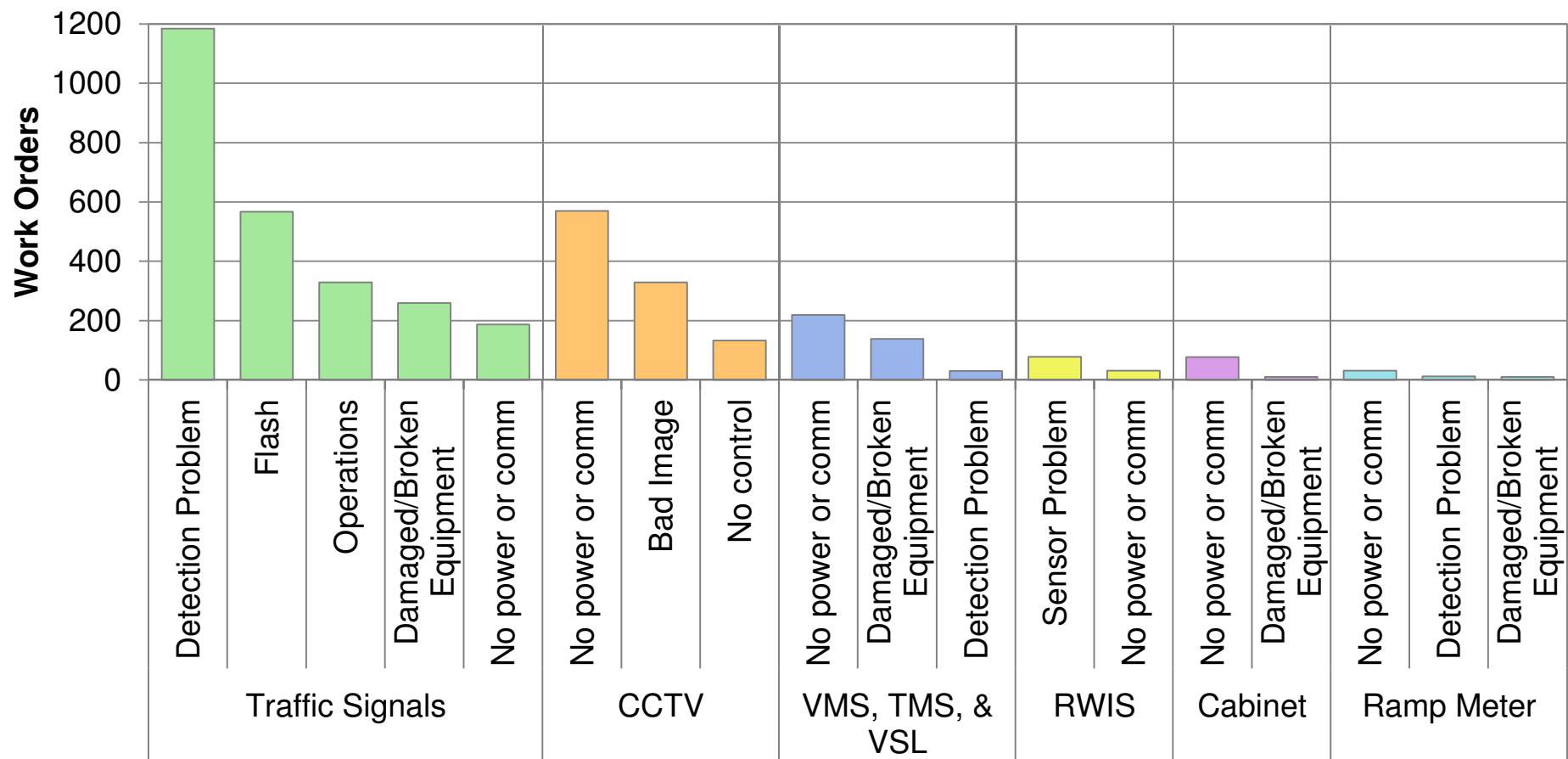
**Metric: Purdue Phase Termination**  
**Detection Requirements: None**

4 Too many ped calls



# Work Orders for UDOT ATMS

# Work Orders for ATMS Equipment  
July 2015 to July 2016

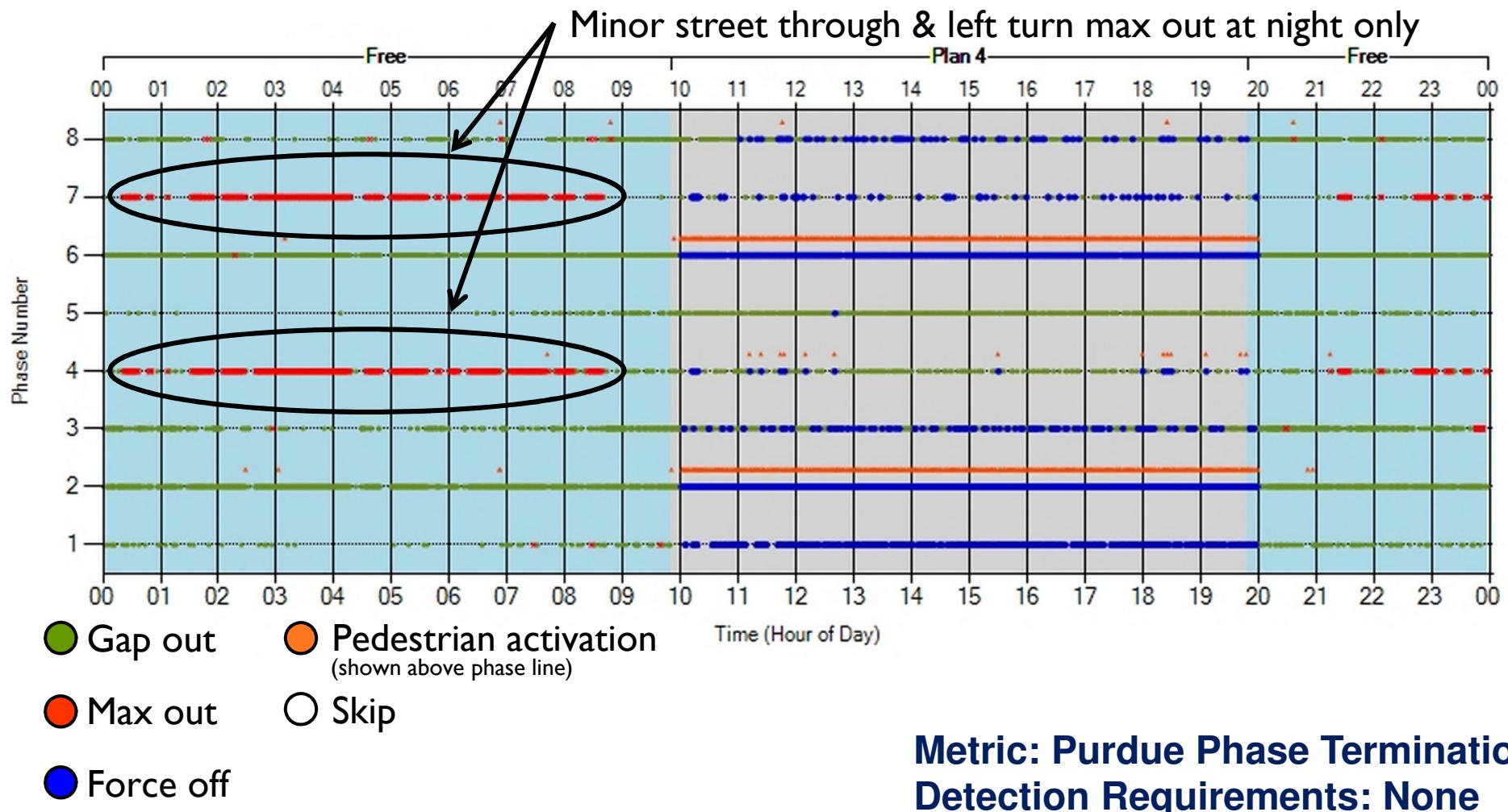


# Troubleshooting with SPMs

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

**Before**

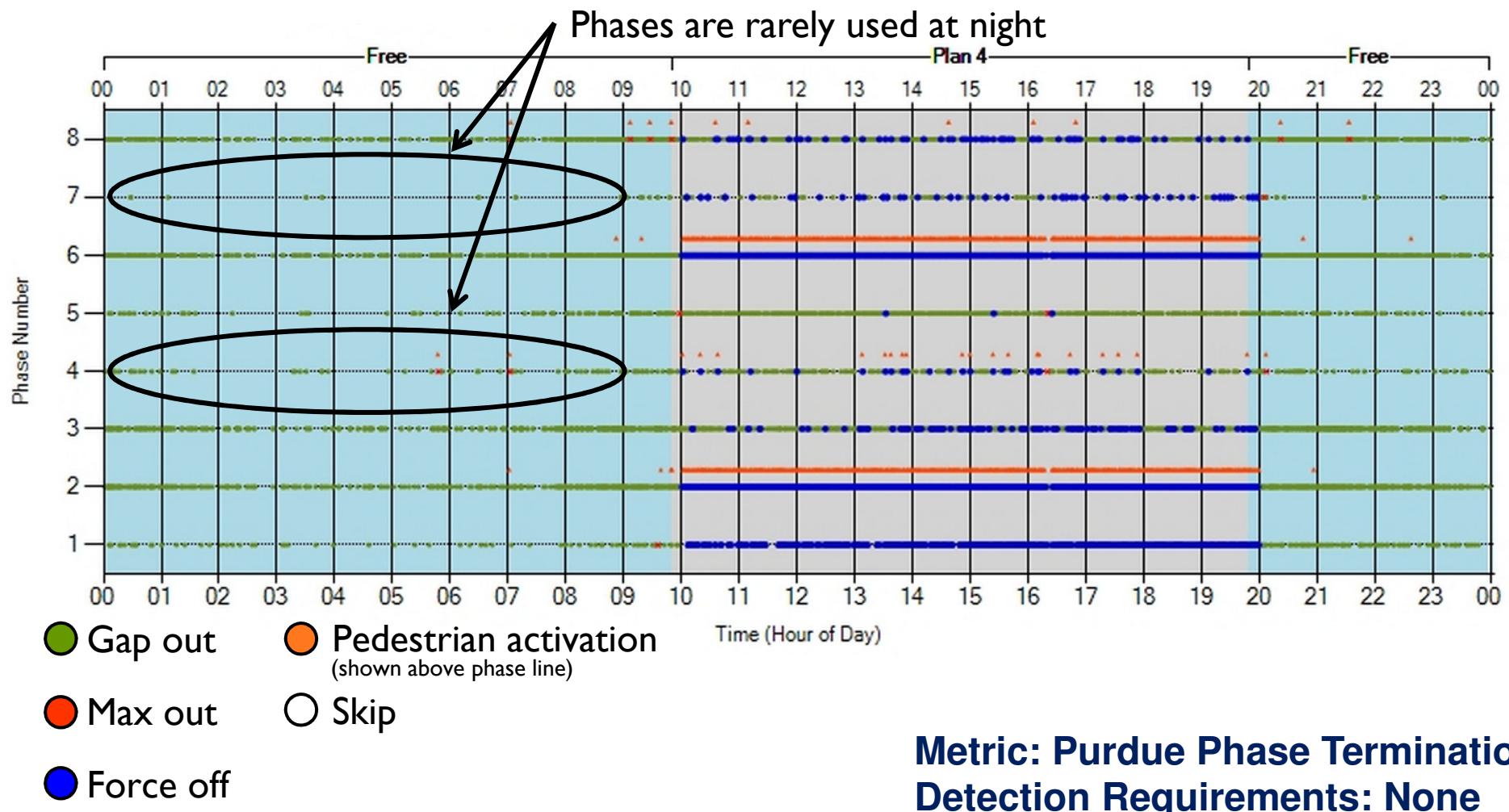
Video detection not working at night



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

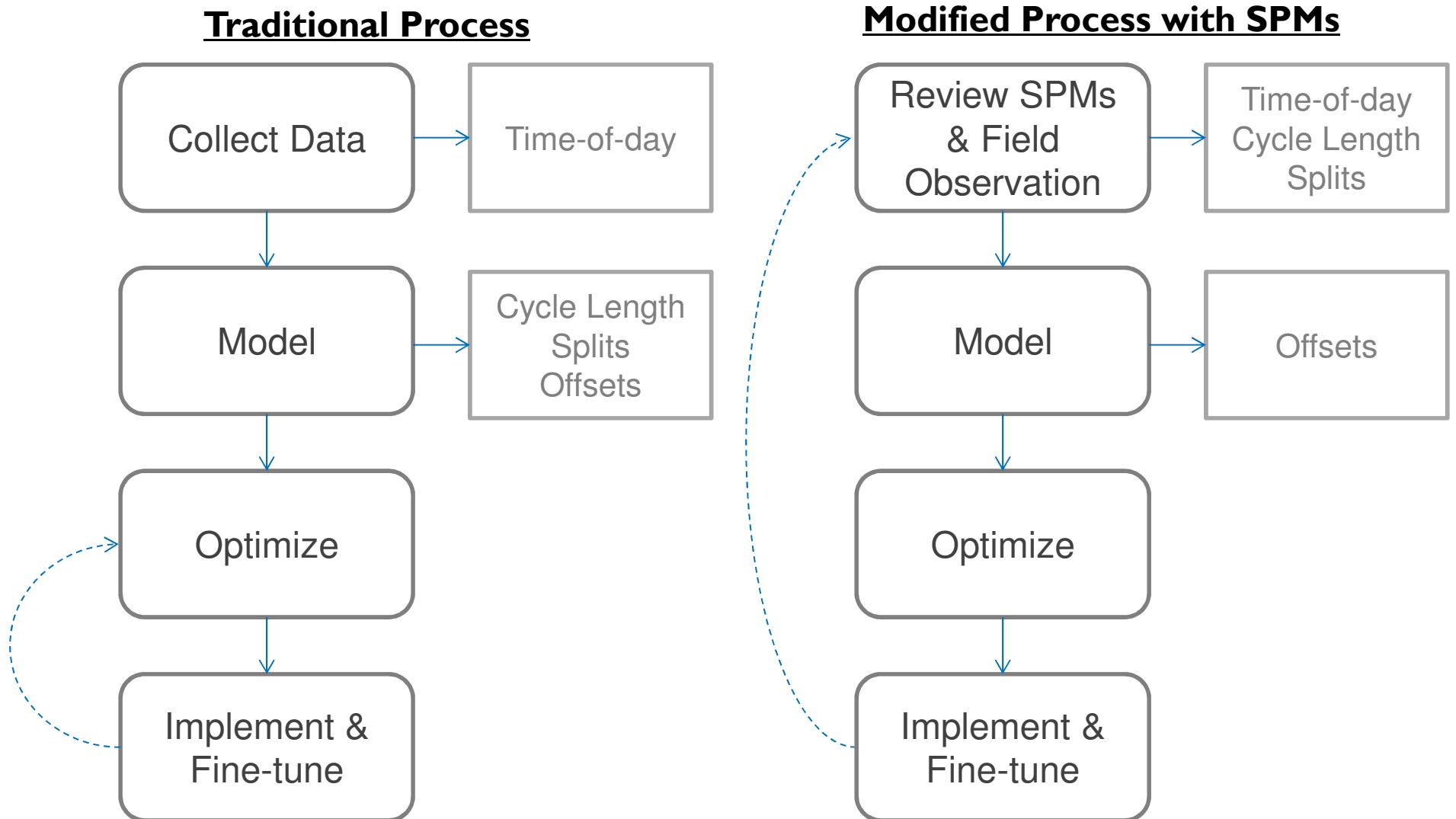
## After

## • New detection technology installed



# Signal Optimization with SPMs

# Optimization with SPMs



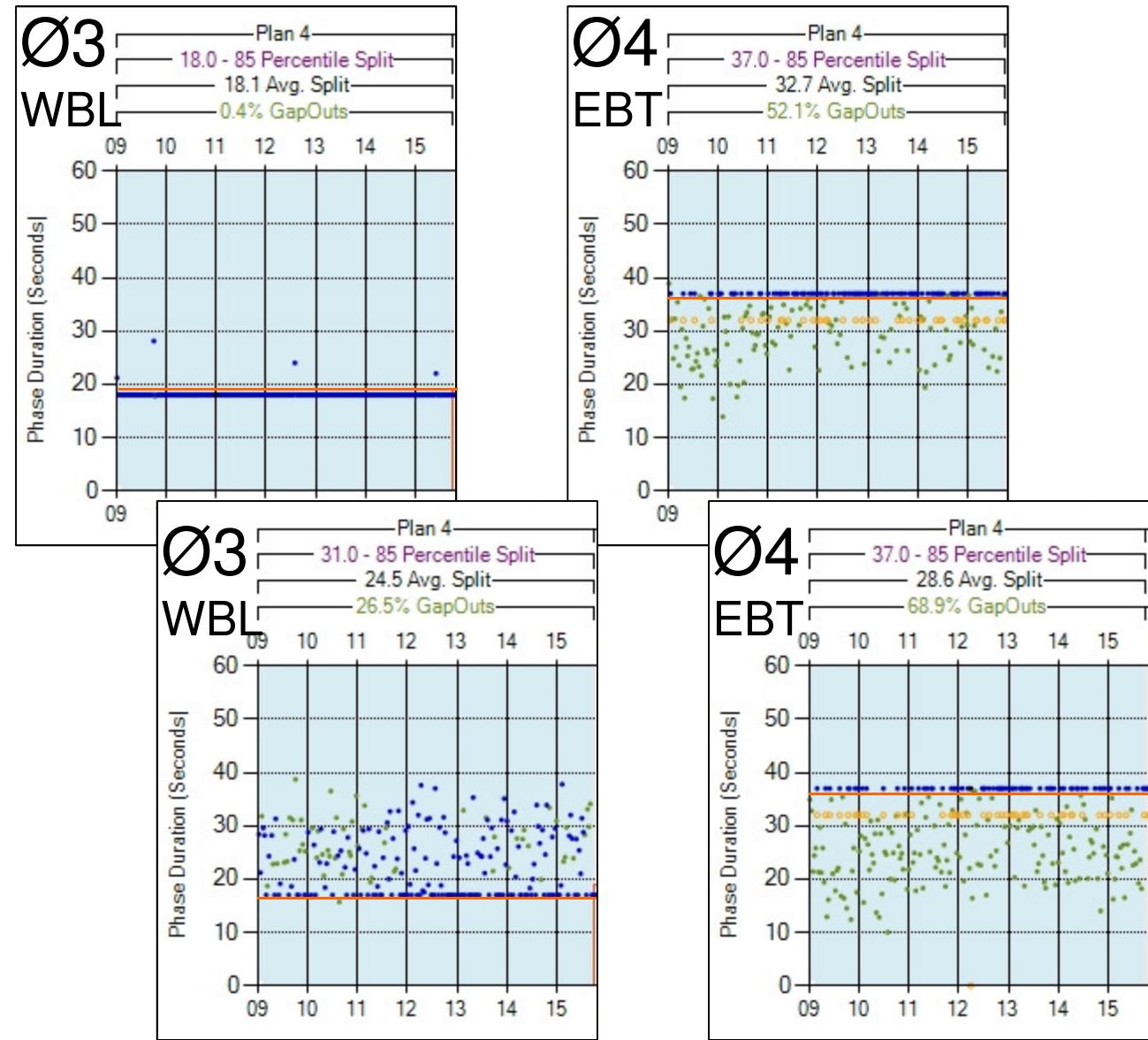
# Evaluate Impact of Timing Change

- Before:

1 2 | 3 4  
5 6 | 7 8

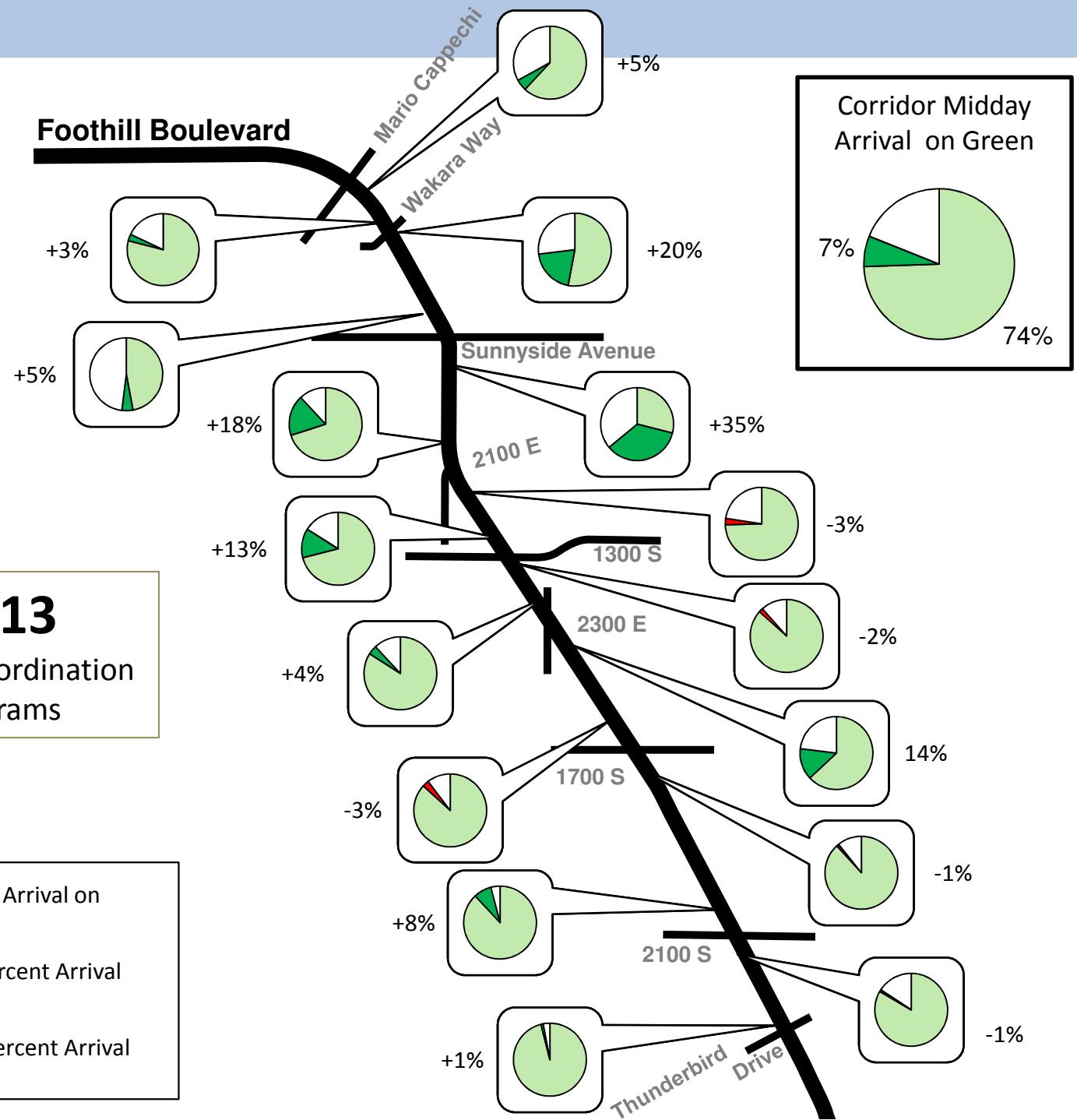
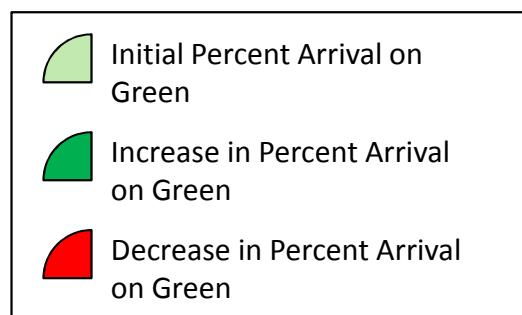
- After:

1 2 | 4 3  
5 6 | 7 8



# Benefits Reporting

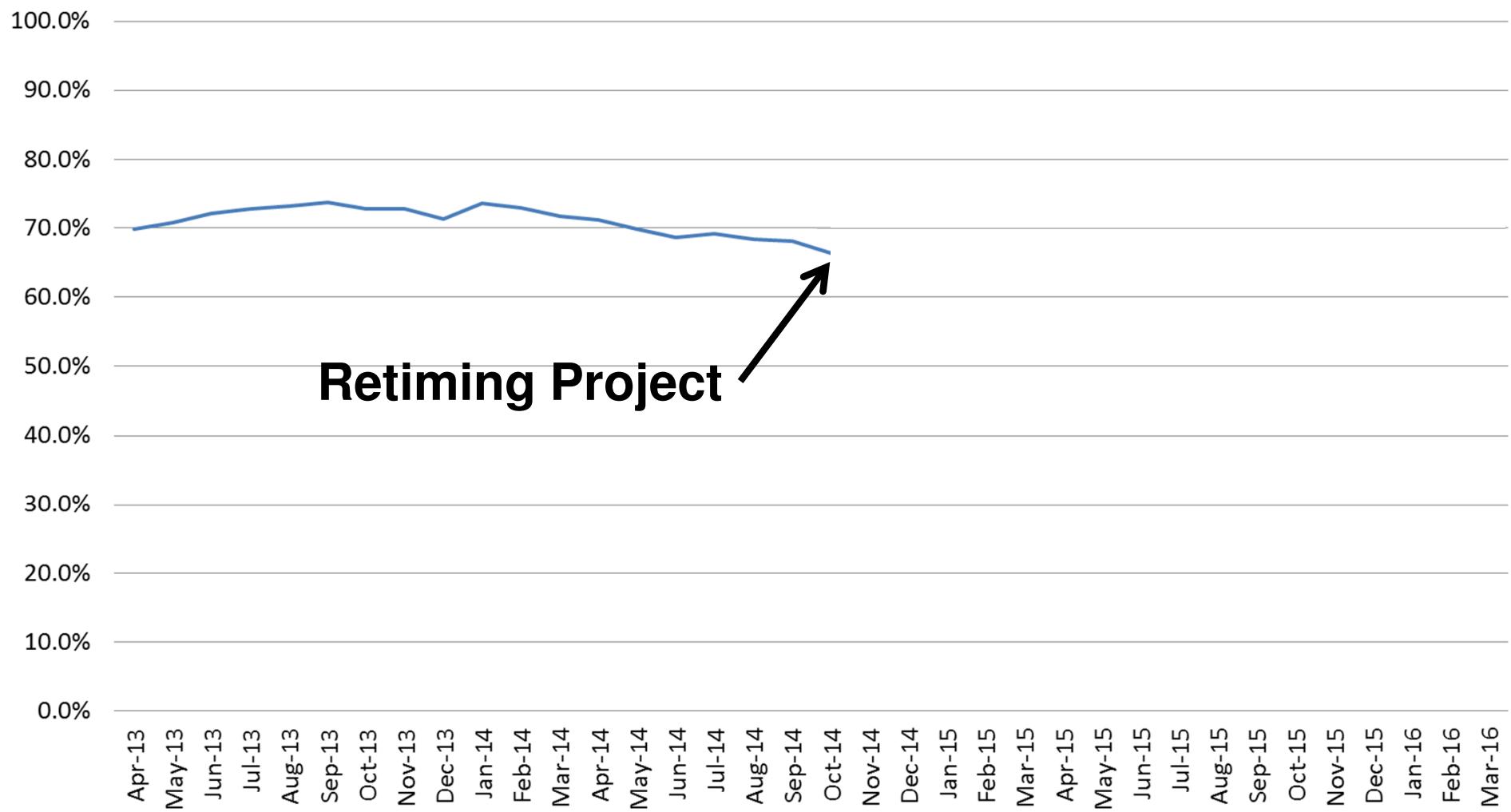
**2013**  
Purdue Coordination  
Diagrams



# Monitor Trends

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

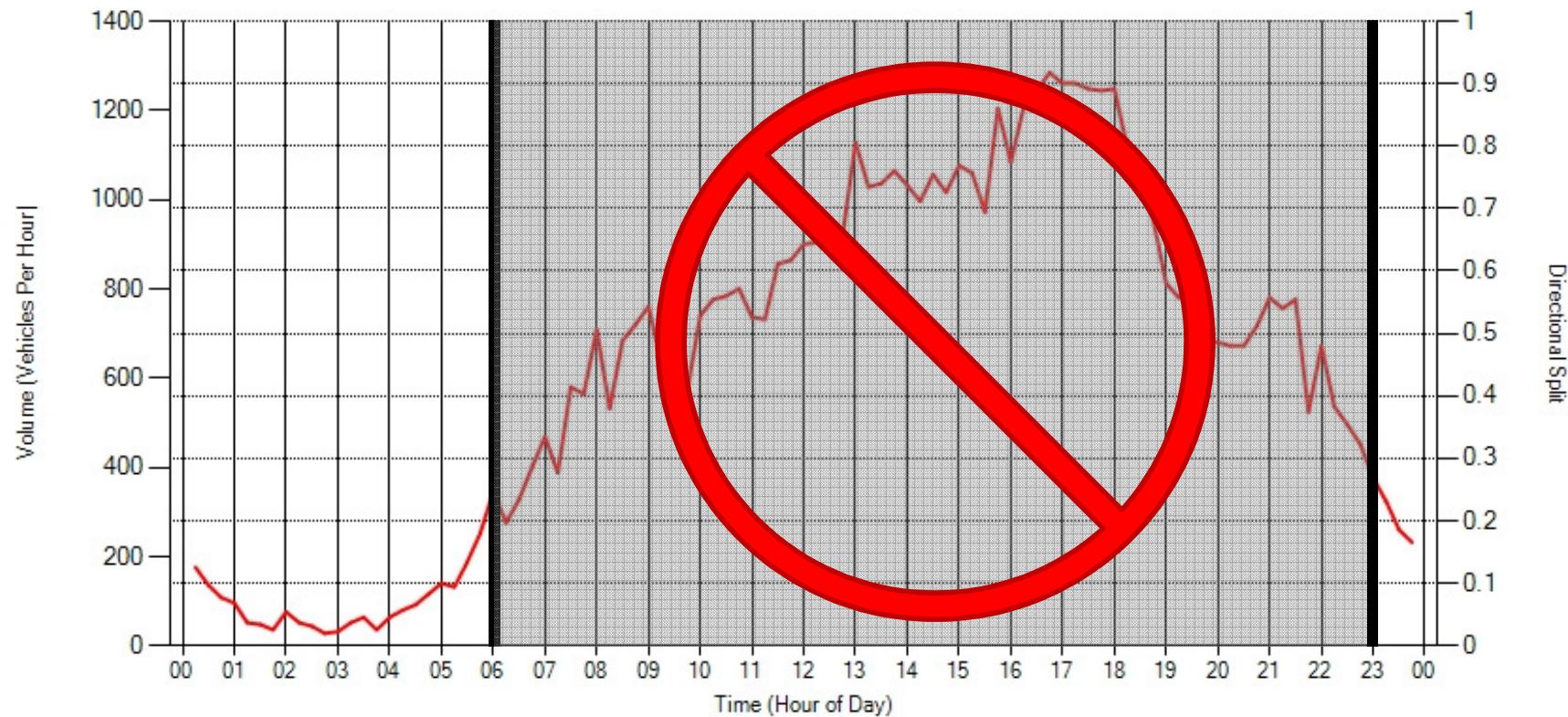
10:00 AM to 2:00 PM Monday through Friday



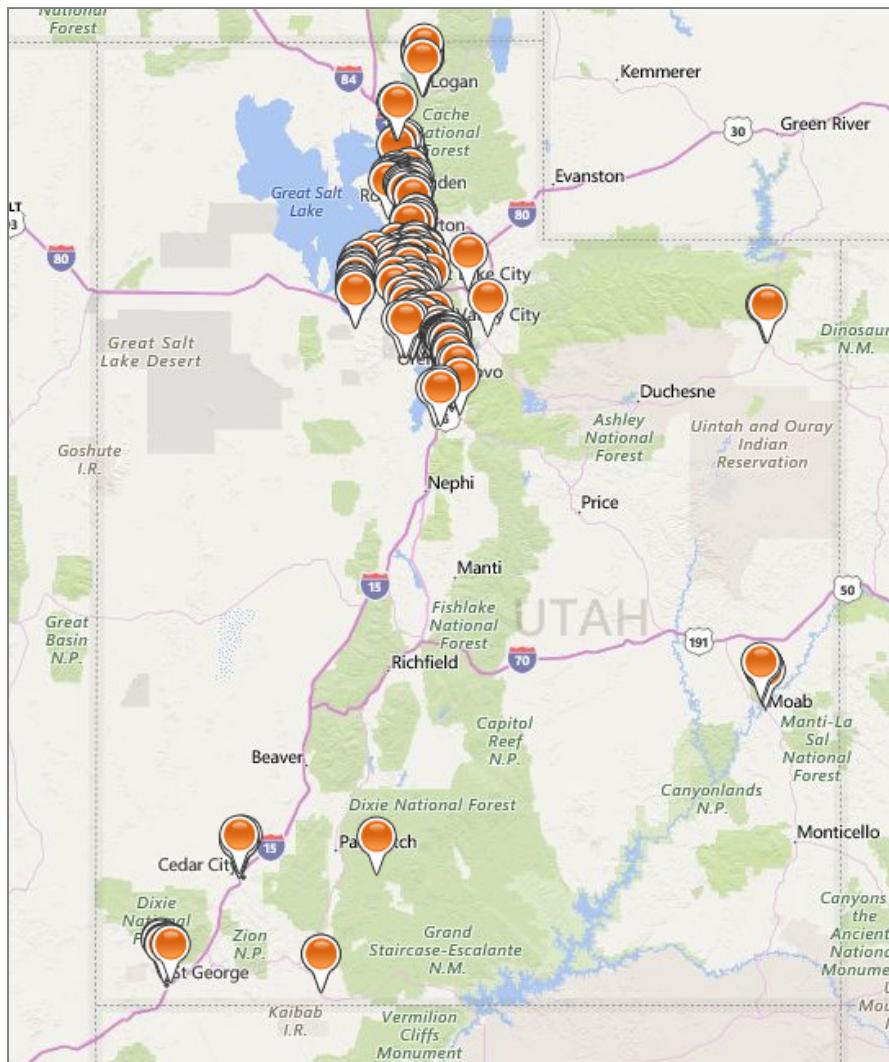
# SPM Use Beyond Signal Operations

# 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



# Planning Data



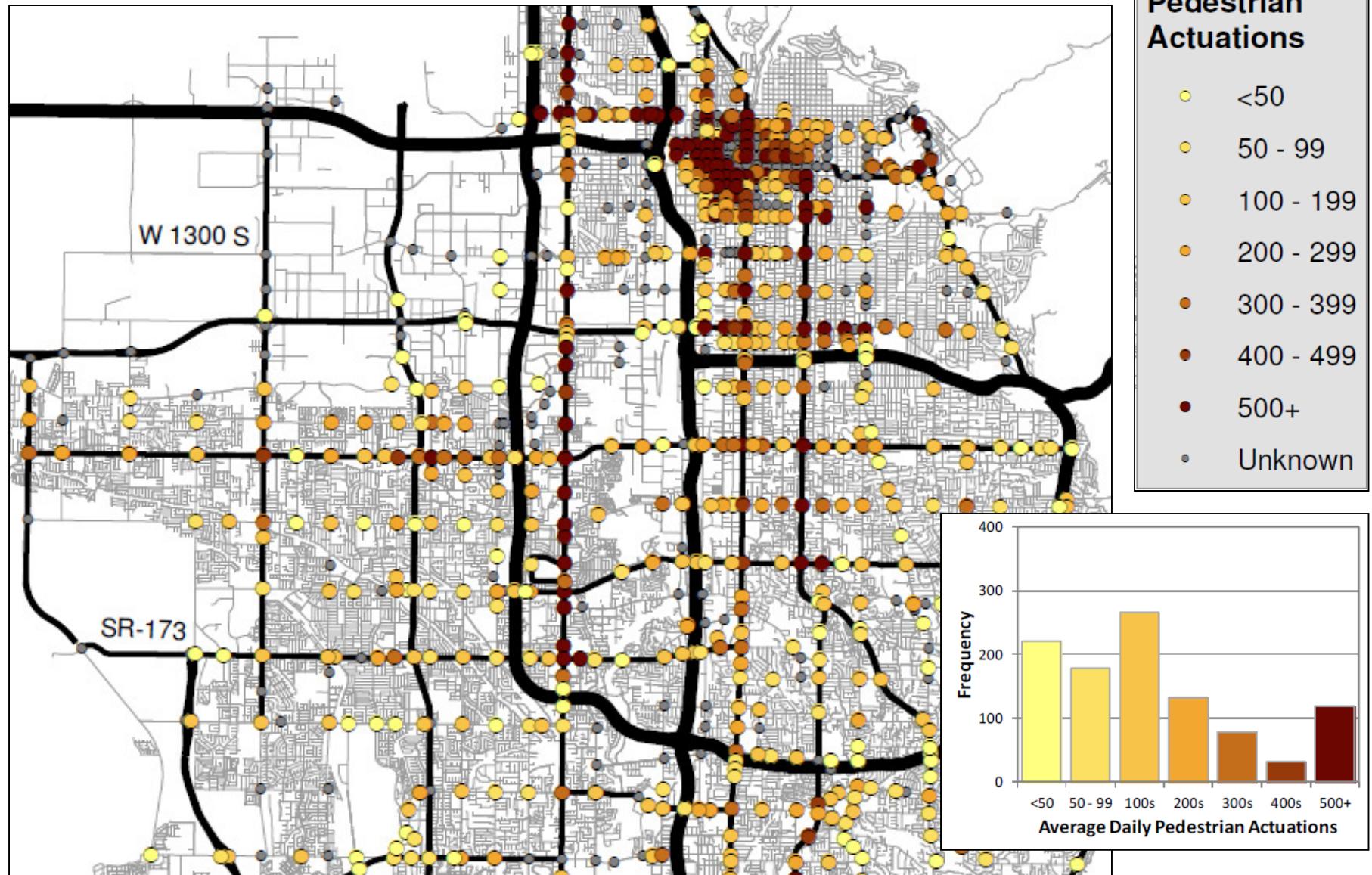
Turning movement or  
Approach counts

**24/7/365**

Available at **333** signals

28% of State signals!

# Active Transportation



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



## Signal Performance Metrics



Charts Reports Log Action Taken Links FAQ

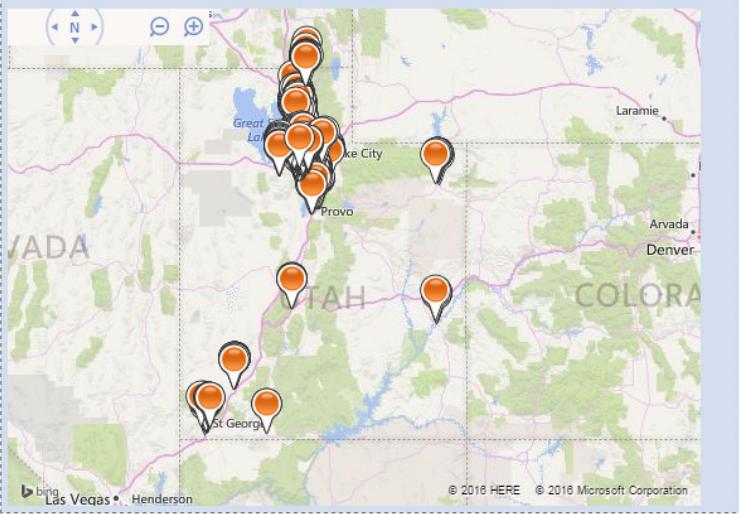
-> Signal Metrics

Selected Signal  
No Signal Selected

Signals  
Region: All Metric Type: All Filter: Signal Id

**Signal List**

**Map**



Time Y Axis Maximum: 150  
Volume Y Axis Maximum: 2000  
Volume Bin Size: 15  
Dot Size: Small  
 Show Plan Statistics  
 Show Volumes  
[Export Data](#)  
 Upload Current Data

Dates  
Start Date: 1/25/2016 ... 12:00 AM  
End Date: 1/25/2016 ... 11:59 PM  

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



### 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***



ITE 3-part Webinar  
April, May, June 2014

BOOKSTORE EMPLOYMENT CENTER TECHNICAL INFORMATION

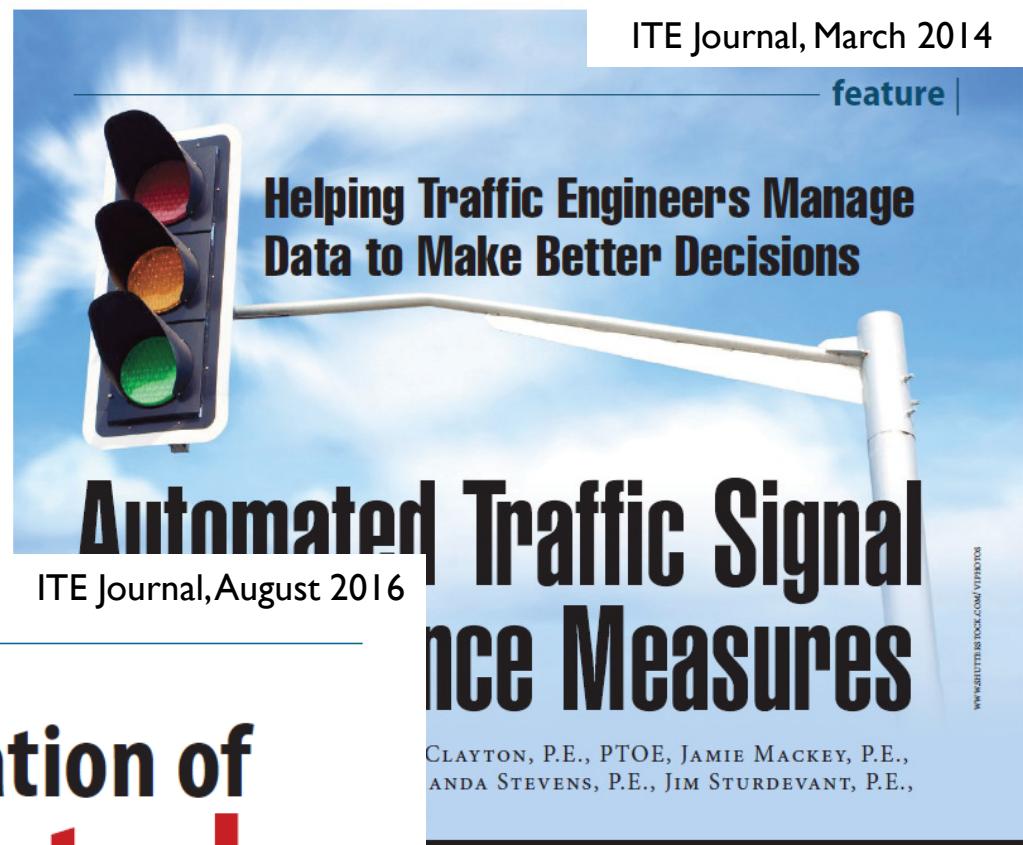
ABOUT ITE JOIN ITE TODAY! COUNCILS

Automated Traffic Signal Performance Measures



# Implementation of Automated Traffic Signal Performance Measures

BY CHRISTOPHER M. DAY, PH.D., MARK TAYLOR, P.E., PTOE,  
JAMIE MACKEY, P.E., PTOE, ROB CLAYTON, P.E., PTOE,  
SHITAL K. PATEL, P.E., GANG XIE, P.E., HOWELL LI,  
JAMES R. STURDEVANT, P.E., AND DARCY BULLOCK, P.E.



ITE Journal, March 2014  
feature |

## Helping Traffic Engineers Manage Data to Make Better Decisions

# Automated Traffic Signal Performance Measures

ITE Journal, August 2016

CLAYTON, P.E., PTOE, JAMIE MACKEY, P.E.,  
ANDA STEVENS, P.E., JIM STURDEVANT, 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 for signal coordination with neighboring jurisdictions. Inize activities when resources are constrained.

# AASHTO

## AASHTO INNOVATION INITIATIVE

### AII

- AII Home
- About AII
- Focus Technologies
- Executive Committee
- Feedback
- Additionally Selected Technologies
- AII Solicitation
- Lead States Team Support

### Automated Traffic Signal Performance Measures

AASHTO > AASHTO Innovation Initiative > Automated Traffic Signal Performance Measures

# Automated Traffic Signal Performance Measures



### Implementation

### Hand-Outs

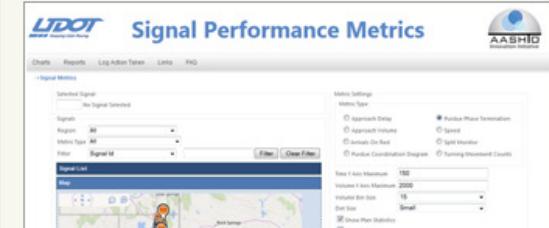
### Additional Resources

### 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 USEAGE/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

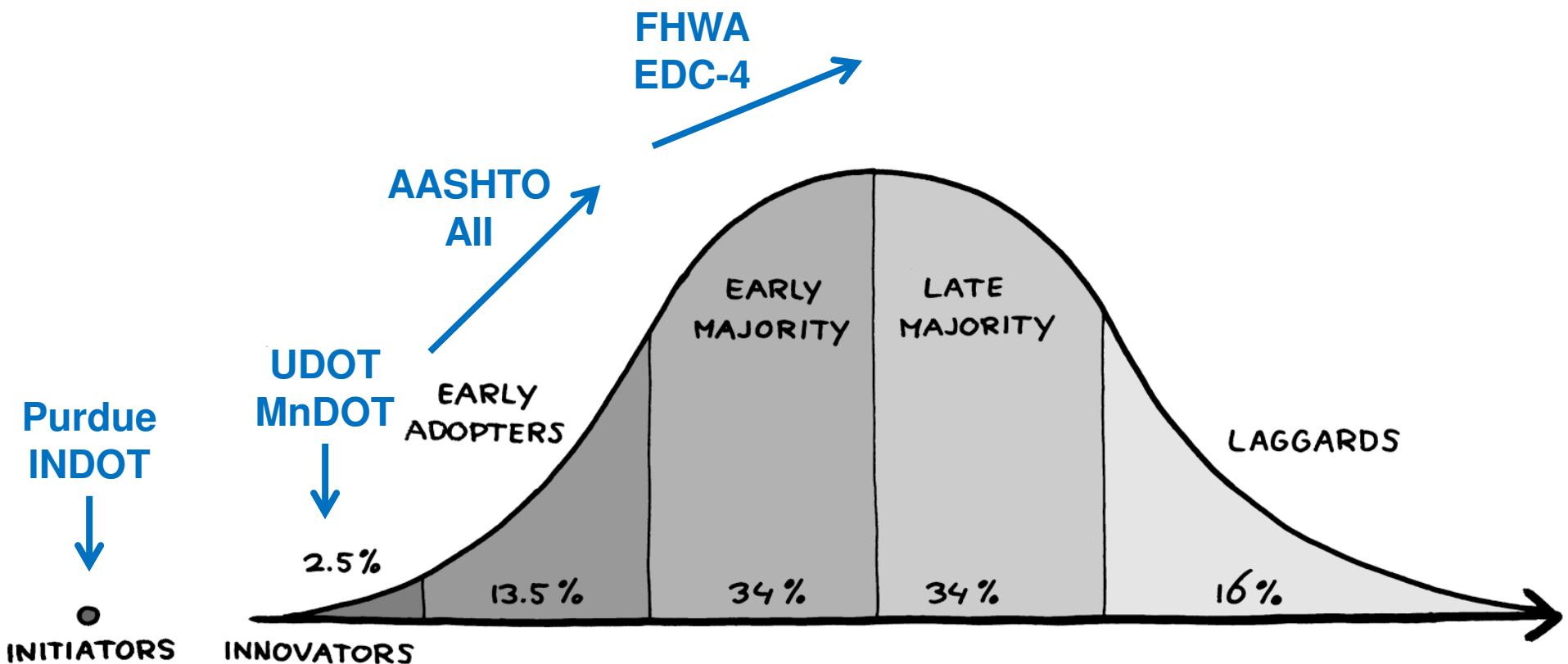
[View EDC-4 Regional Summit information](#)

[View EDC-4 webinars](#)

[EDC-4 Generic Summit Agenda](#)

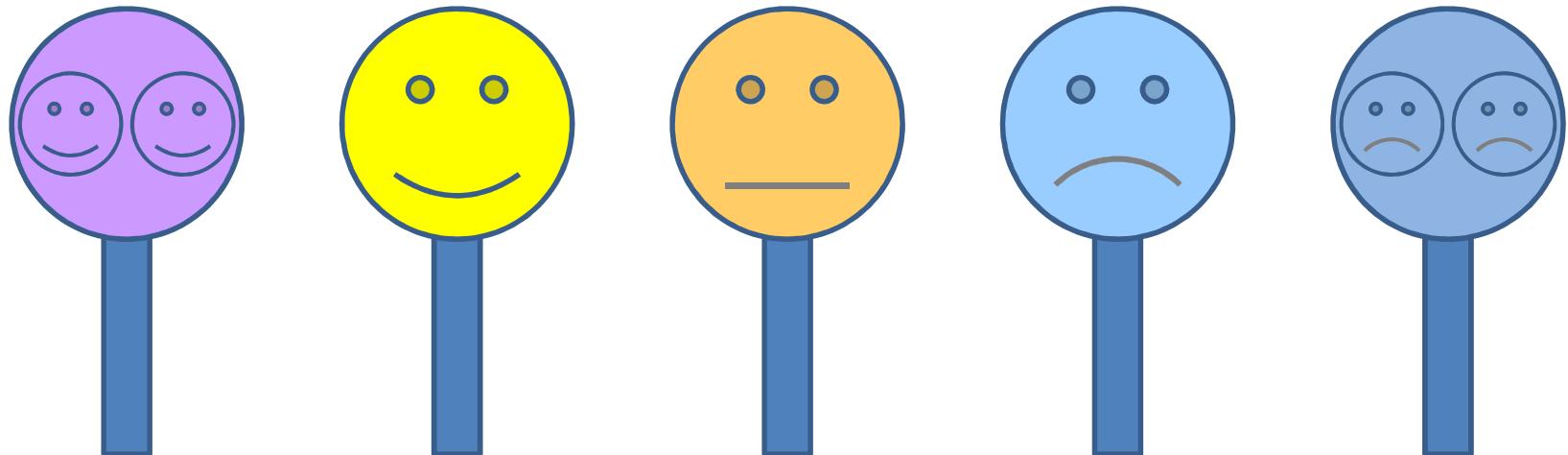
### EDC Rounds

# Innovation/Adoption Curve



# UDOT Signal Timing Focus Group (July 2014)

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

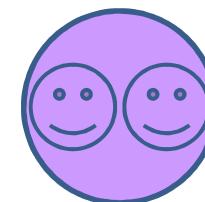
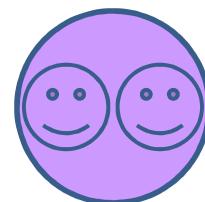
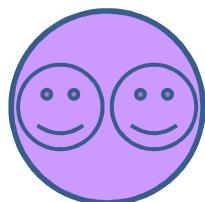


## Focus Group Key Findings (July 2014)

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

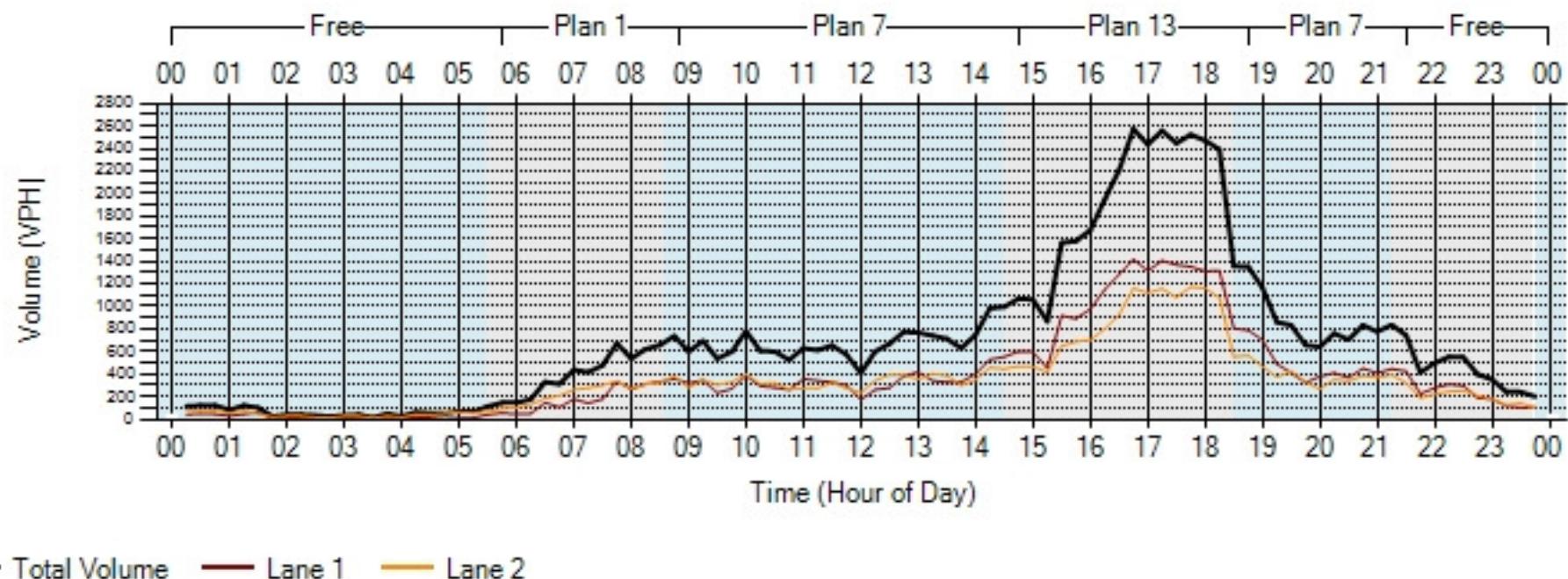
- Note: Evaluate the VOLUME on the PCD charts, not the phase data*
- Is count channel configured correctly in SPM Config Tool?
  - Is ECPI Log enabled for count channel?
  - Is the detector working?
  - Is the detector communicating to the controller?
  - Try resetting the sensor and VERIFY with Upload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

# Determine Approach Capacity

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

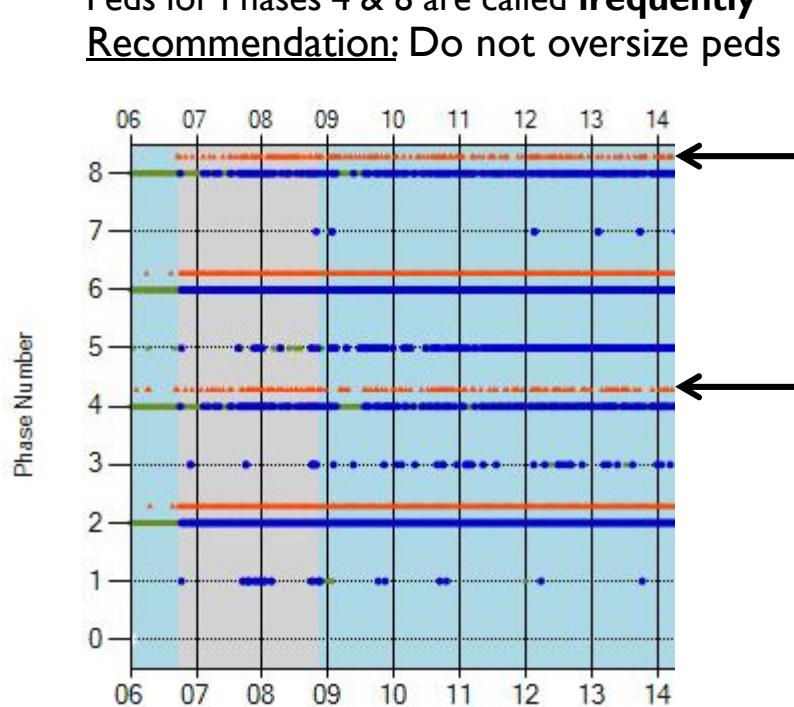
## Northbound Thru

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

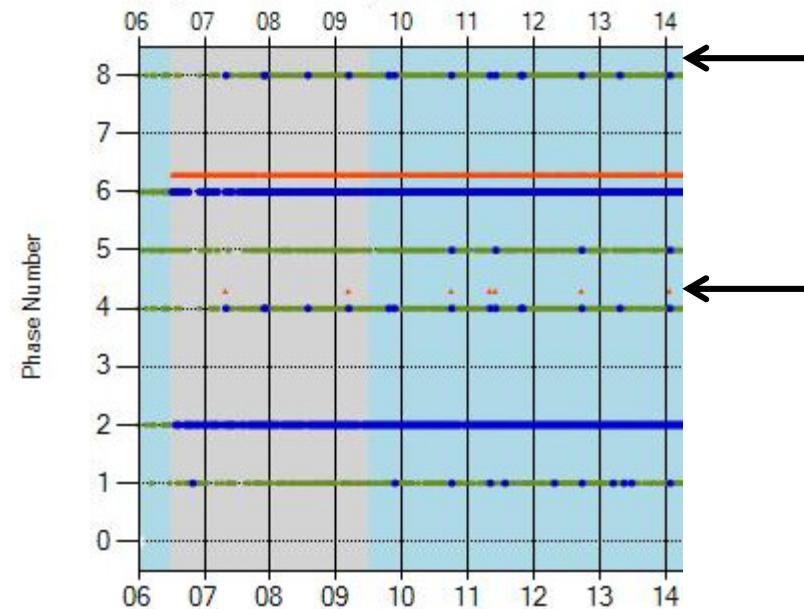


# “Can we oversize the peds?”

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

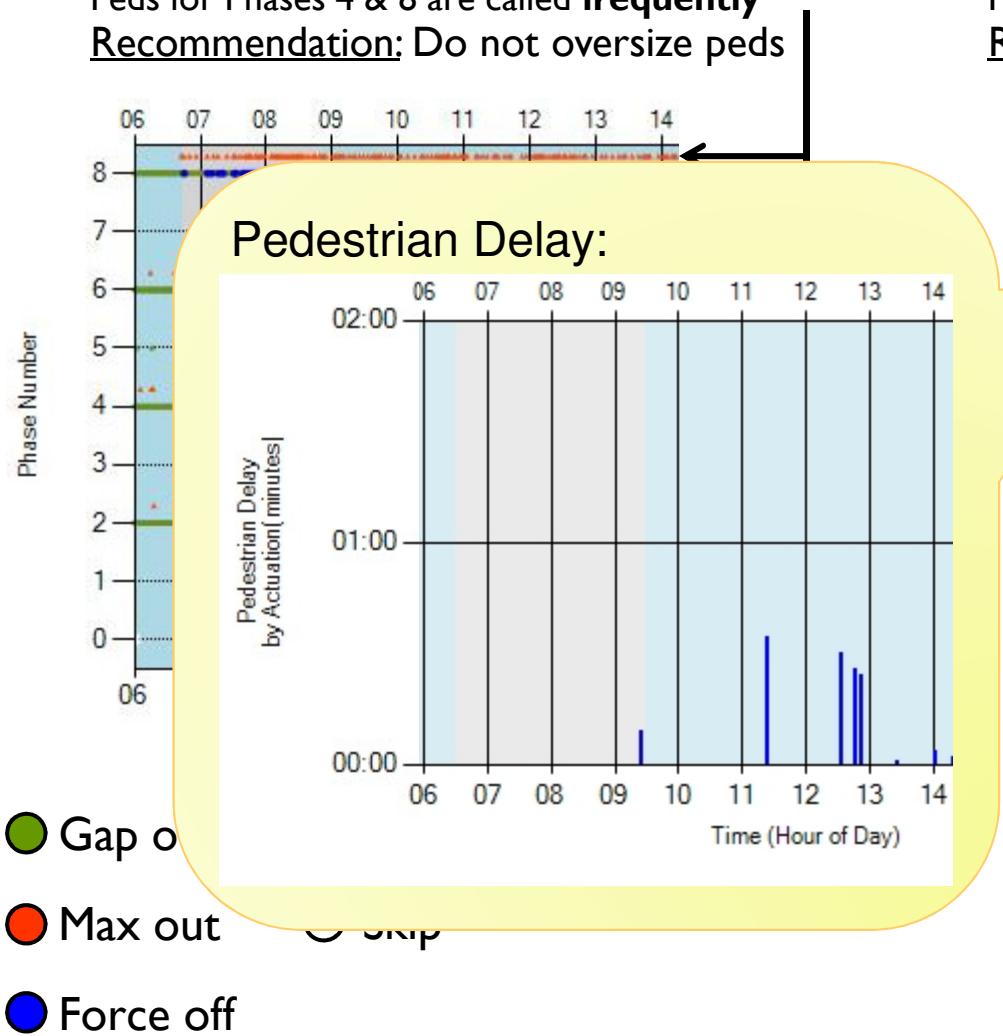


- Gap out      ● Pedestrian activation  
(shown above phase line)
- Max out      ○ Skip
- Force off

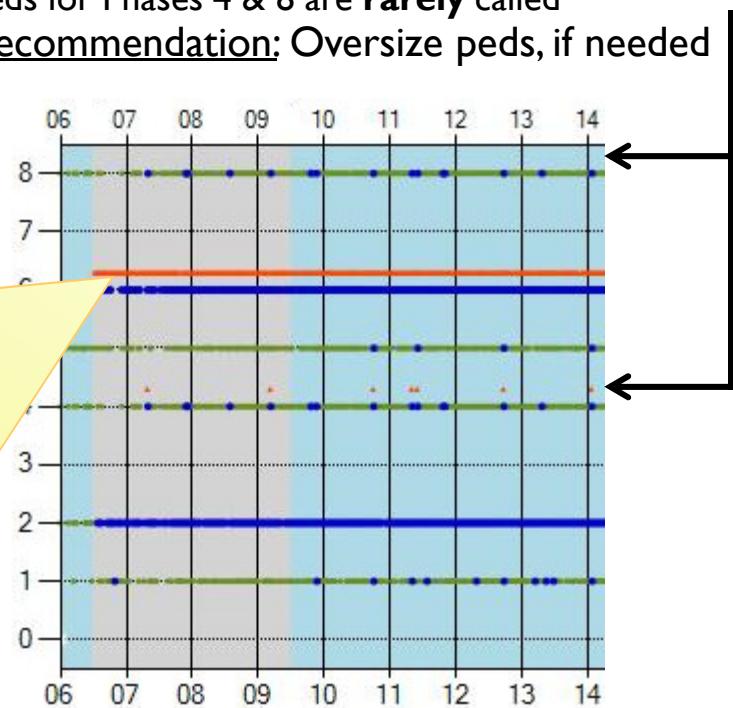
**Metric: Purdue Phase Termination**  
**Detection Requirements: None**

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