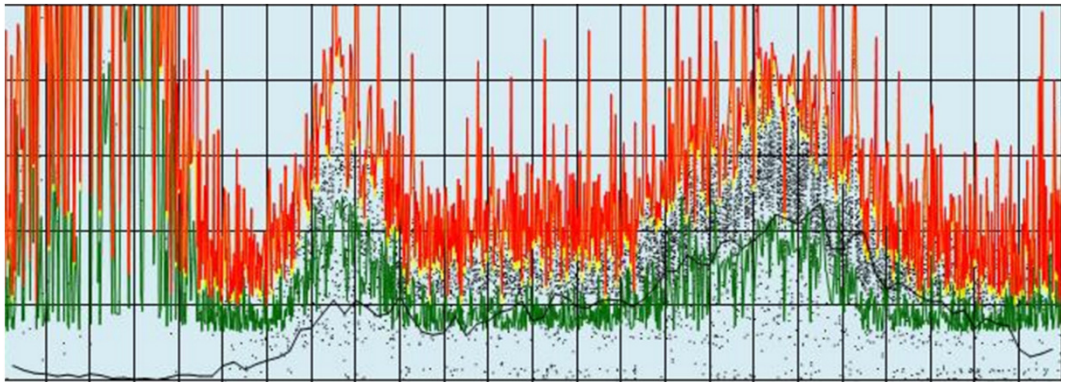


Automated Traffic Signal Performance Measures: UDOT's Experience

Mark Taylor, P.E., PTOE

Traffic Signal Operations Engineer

Utah Department of Transportation

marktaylor@utah.gov

EDC-4 • Regional Summit • October 25, 2016

UDOT Keeping Utah Moving

Brief Utah Update

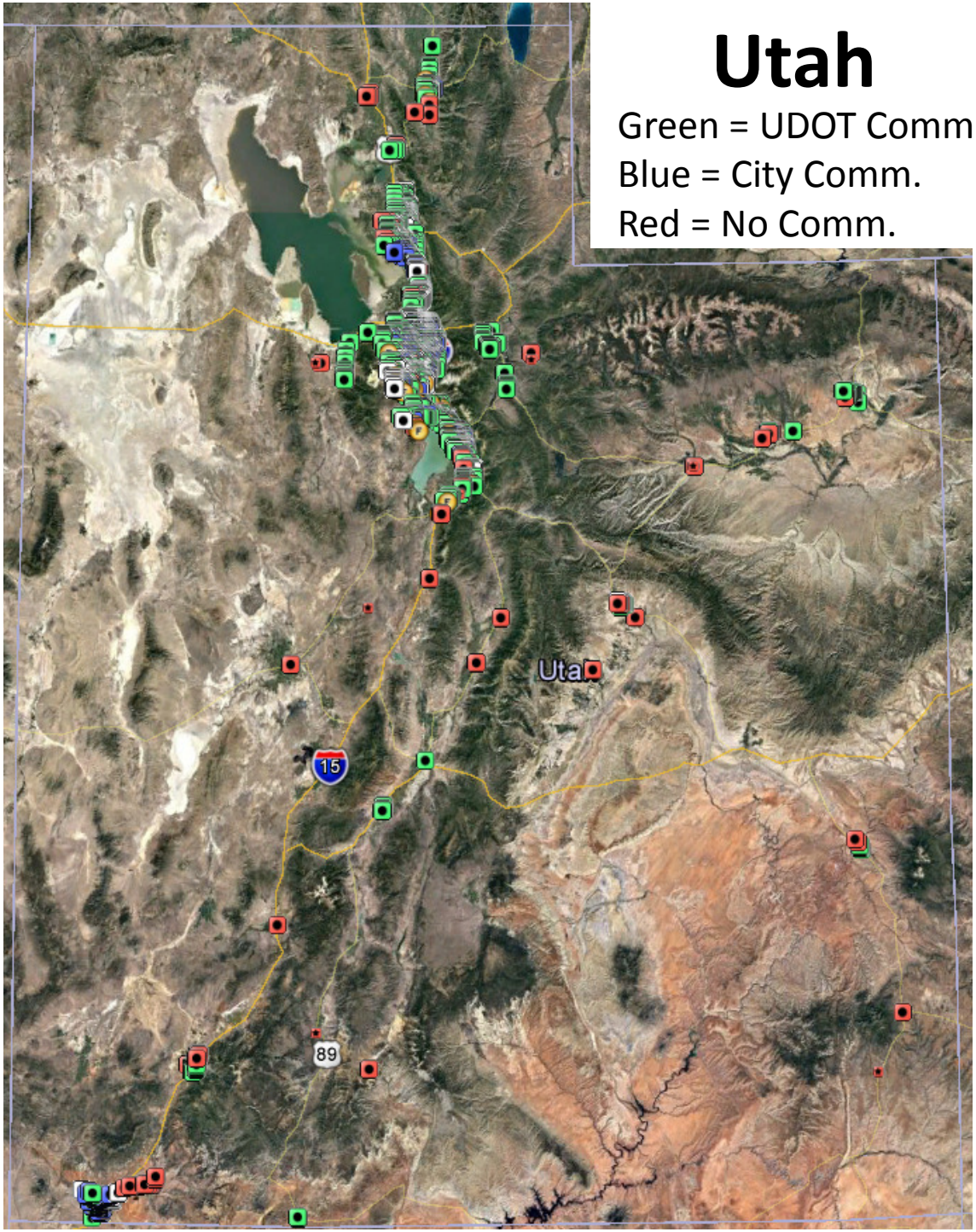
- 2012 Traffic Signals in the State of Utah
  - 1192 owned and operated by UDOT (59%)
  - 820 owned and operated by cities /counties (41%)

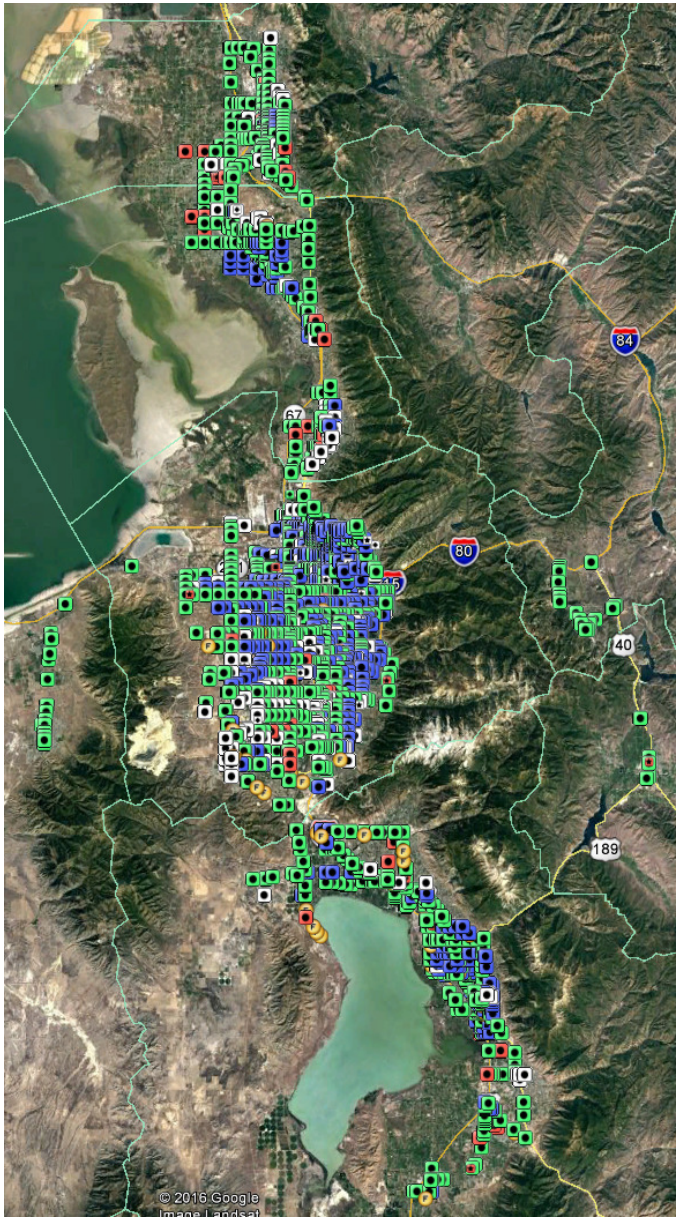
- All cities share same ITS communications
  - 93% of UDOT signals connected
  - 79% of non-UDOT signals connected

- All cities in Utah & UDOT share same ATMS

Utah

Green = UDOT Comm.
Blue = City Comm.
Red = No Comm.





Wasatch Front

UDOT's Road Map

Vision: Keeping Utah Moving

Mission: Innovating transportation solutions that strengthen Utah's economy and enhance quality of life.

Strategic Goals:

1. Zero Crashes, Injuries and Fatalities
   Yellow & Red Actuations, Speed, Preemption Details
2. Optimize Mobility
   PCD, Split Monitor, Volumes, Purdue Link Pivot, Purdue Split Failure
3. Preserve Infrastructure
   Purdue Phase Termination, Daily Detector Problem Email

UDOT Keeping Utah Moving

Objective	Automated Traffic Signal Performance Measures																
	Approach Volumes	Turning Movement Counts	Split Monitor	Purdue Phase Termination	Purdue Coordination Diagram	Purdue Travel Time Diagram	Purdue Link Pivot	Purdue Split Failure	Percent Arrivals on Green	Detector Error Alarms	Executive Reports	Yellow & Red Actuations	Approach Delay	Arrivals on Red	Speed	Pedestrian Delay	Preemption Details
Improve Traffic Flows					X	X	X		X		X	X	X	X			
Improve Capacity Allocation	X	X	X	X				X									
Improve Pedestrian Service		X	X	X												X	
Improve Bicycle Service		X	X	X													
Maintain Vehicle & Pedestrian Detection	X	X		X						X							
Maintaning Preemption																	X
Minimize Pollution and Noise					X	X	X	X	X						X		
Automate Traffic Counts & Studies	X	X									X				X		
Develop Origin-Destination Data						X											
Improve Safety					X			X				X			X		X

Source: UDOT Traffic Signal Management Plan -Table 4 Page 13: http://www.udot.utah.gov/main/uconowner.gf?n=29256708738824069

UDOT Asset Management Tiers (2015 & Prior)

- Asset Management Tiers range from 1 to 3
- Tier 1 assets:
  - Highest value combined with highest risk of negative financial impact for poor management.
  - Very important to UDOT.
  - Receive separate funding source.
  - Targets and measures are set and tracked.

Tier 1 Assets
Pavement
Bridges

Tier 2 Assets
ATMS / Signal Devices
Pipe Culverts
Signs
Barriers & Walls
Rumble Strips
Pavement Markings

Tier 3 Assets
Cattle Guards
Interstate Lighting
Fences
Curb & Gutter
Rest Areas

Source: https://www.udot.utah.gov/main/uconowner.gf?n=15663419239657232

UDOT Asset Management Tiers (2016 & Future)

- Asset Management Tiers range from 1 to 3
- Tier 1 assets:
  - Highest value combined with highest risk of negative financial impact for poor management.
  - Very important to UDOT.
  - Receive separate funding source.
  - Targets and measures are set and tracked.

Tier 1 Assets
Pavement
Bridges
ATMS / Signal Devices

Tier 2 Assets
Pipe Culverts
Signs
Barriers & Walls
Rumble Strips
Pavement Markings

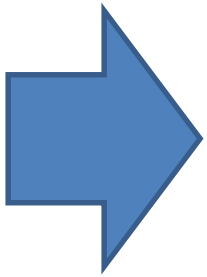
Tier 3 Assets
Cattle Guards
Interstate Lighting
Fences
Curb & Gutter
Rest Areas

Source: https://www.udot.utah.gov/main/uconowner.gf?n=15663419239657232

ATSPM Basic Concept

Automated Data Collection

- Signal controller
- Probe source



Useful Information about Performance

- Signal
- Corridor
- System

Why Model what you can Measure?

Does NOT require Central Traffic Signal Management Software!

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

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

Standard Cont

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 Cleara
9	Phase End Yellow Clearan
10	Phase Begin Red Clearanc
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

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

11-2012

Indiana Traffic Signal Hi Resolution Data Logger Enumerations

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Ray Deer
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Siemens Industry, Inc.

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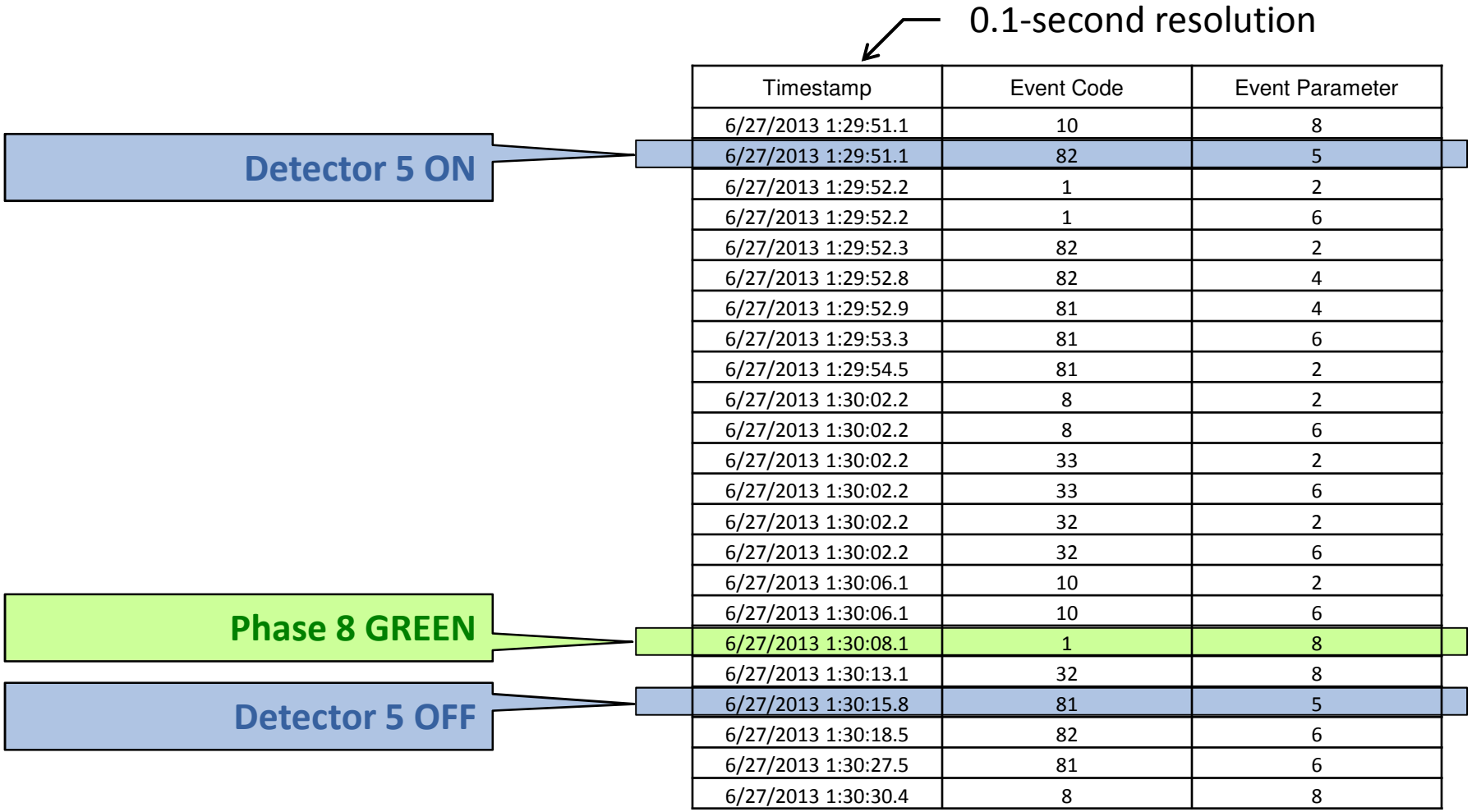
Recommended Citation
Sturdevant, J. R., T. Overman, E. Raamot, R. Deer, D. Miller, D. M. Bullock, C. M. Day, T. M. Brennan, H. Li, A. Hainen, and S. M. Remias. *Indiana Traffic Signal Hi Resolution Data Logger Enumerations*. Publication . , Indiana Department of Transportation and Purdue University, West Lafayette, Indiana, 2012. doi: http://data.datacite.org/10.4231/K4RN35SH.

High-resolution Data



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

System Requirements

High-resolution Controller

Communications

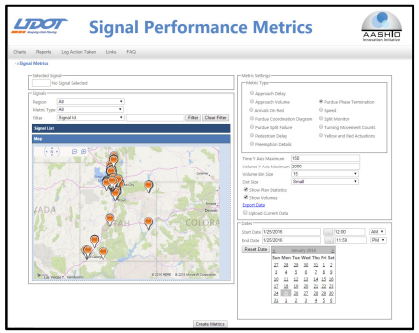
1) Get .dat Files

2) Translate Files

.dat → .csv

3) Store in Database

Server



Software

Detection
(optional)

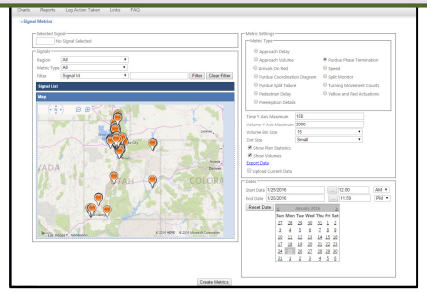
Photo courtesy of the Indiana Department of Transportation

System Requirements

Does NOT require Central Traffic Signal Management Software!

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

Server



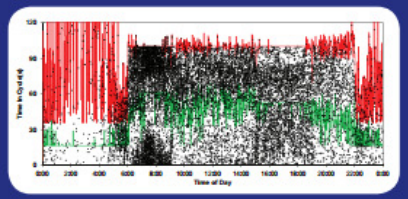
Software

Detection
(optional)

Photo courtesy of the Indiana Department of Transportation

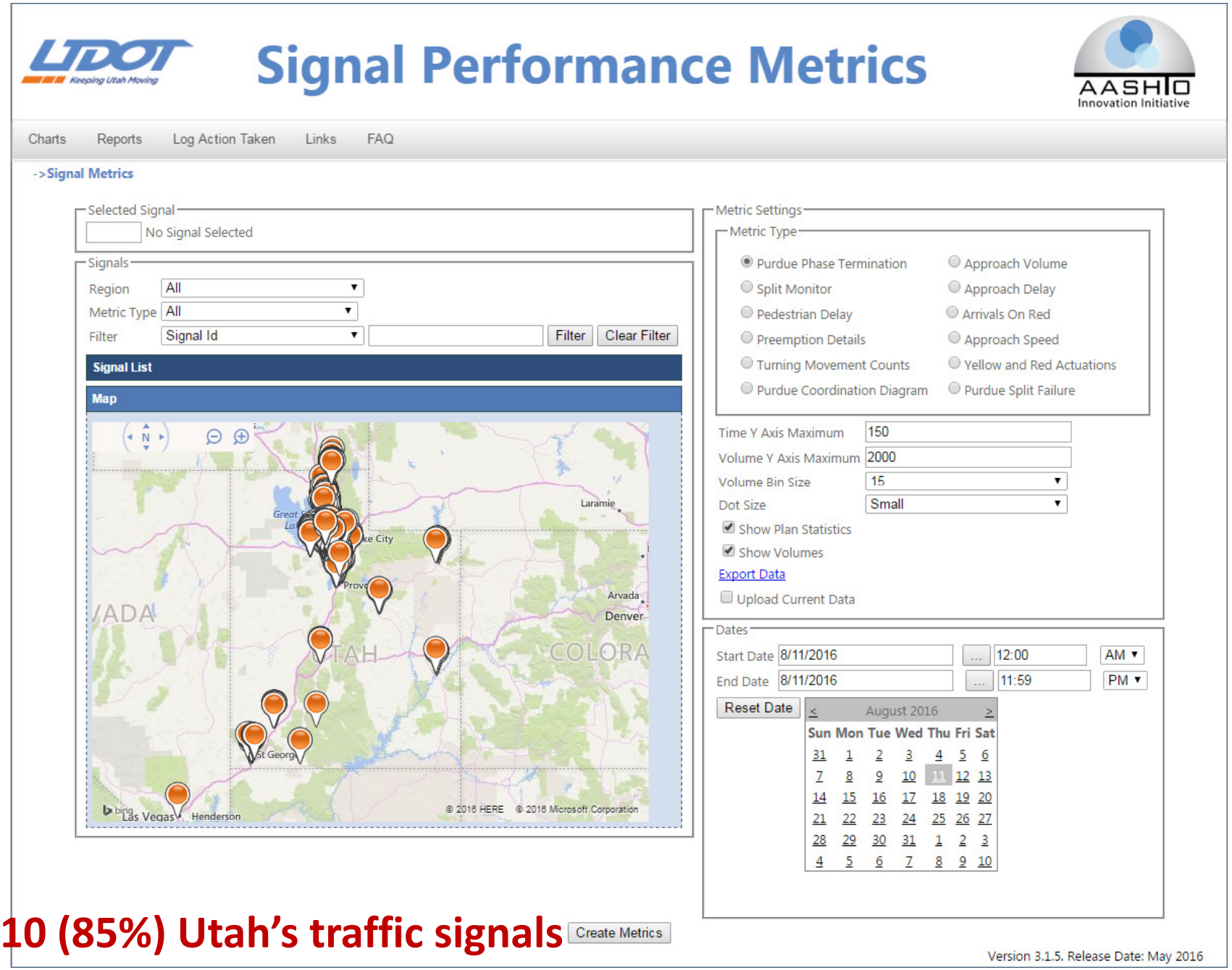
PERFORMANCE MEASURES FOR TRAFFIC SIGNAL SYSTEMS

An Outcome-Oriented Approach



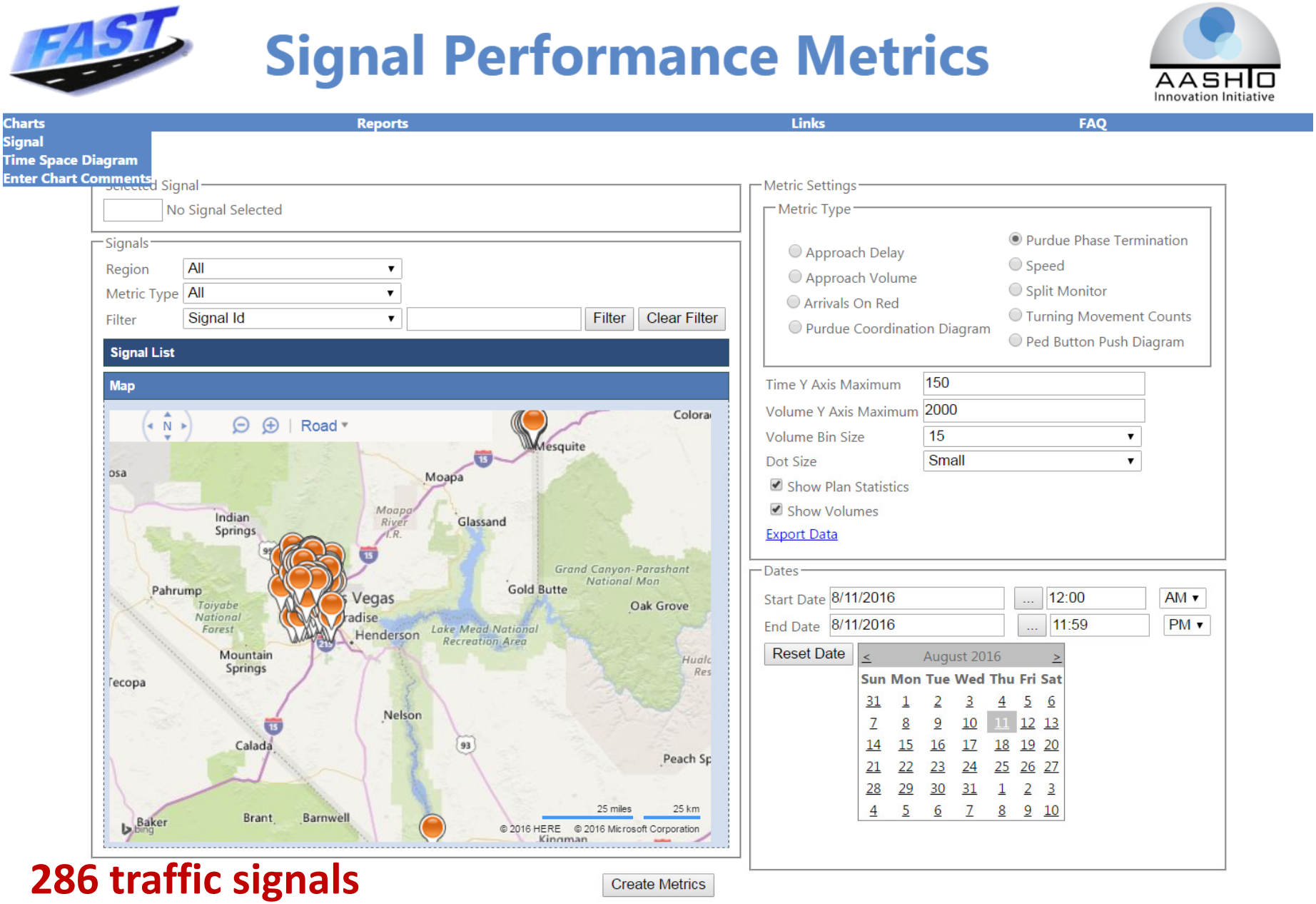
Christopher M. Day, Darcy M. Bullock, Howell Li, Stephen M. Remias, Alexander M. Hainen, Richard S. Freije, Amanda L. Stevens, James R. Sturdevant, and Thomas M. Brennan

http://udottraffic.utah.gov/signalperformancemetrics



1710 (85%) Utah's traffic signals

http://challenger.nvfast.org/spm



286 traffic signals

http://spm.seminolecountyfl.gov/signalperformancemetrics

Signal Performance Metrics

->Signal Metrics

Selected Signal

No Signal Selected

Signals

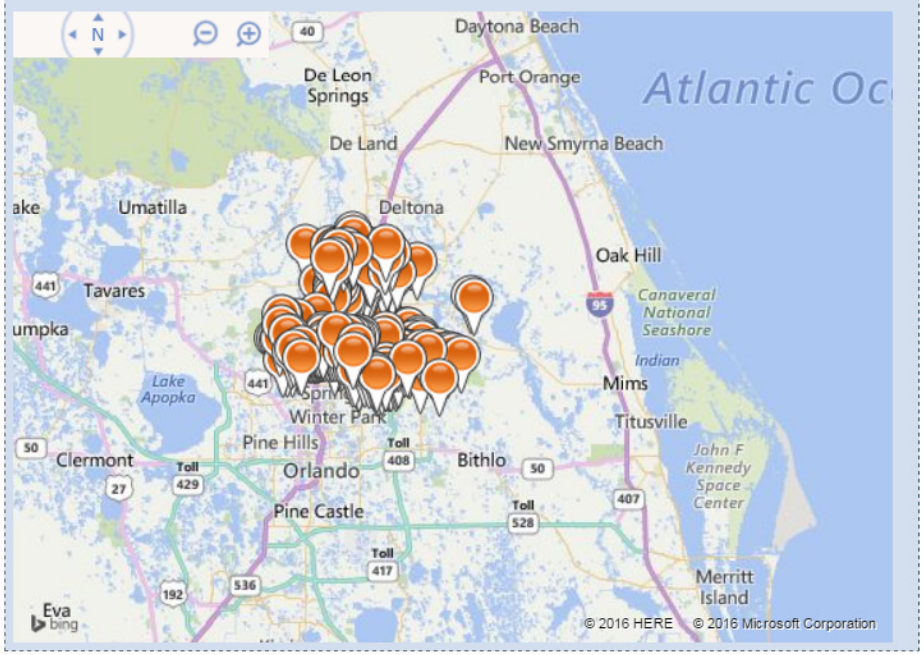
Region: All

Metric Type: All

Filter: Signal Id | Filter | Clear Filter

Signal List

Map



Metric Settings

Metric Type

- Approach Delay
- Approach Volume
- Arrivals On Red
- Purdue Coordination Diagram
- Purdue Phase Termination
- Speed
- Split Monitor
- Turning Movement Counts

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: 8/11/2016 ... 12:00 AM

End Date: 8/11/2016 ... 11:59 PM

Reset Date

August 2016

Sun	Mon	Tue	Wed	Thu	Fri	Sat
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	7	8	9	10

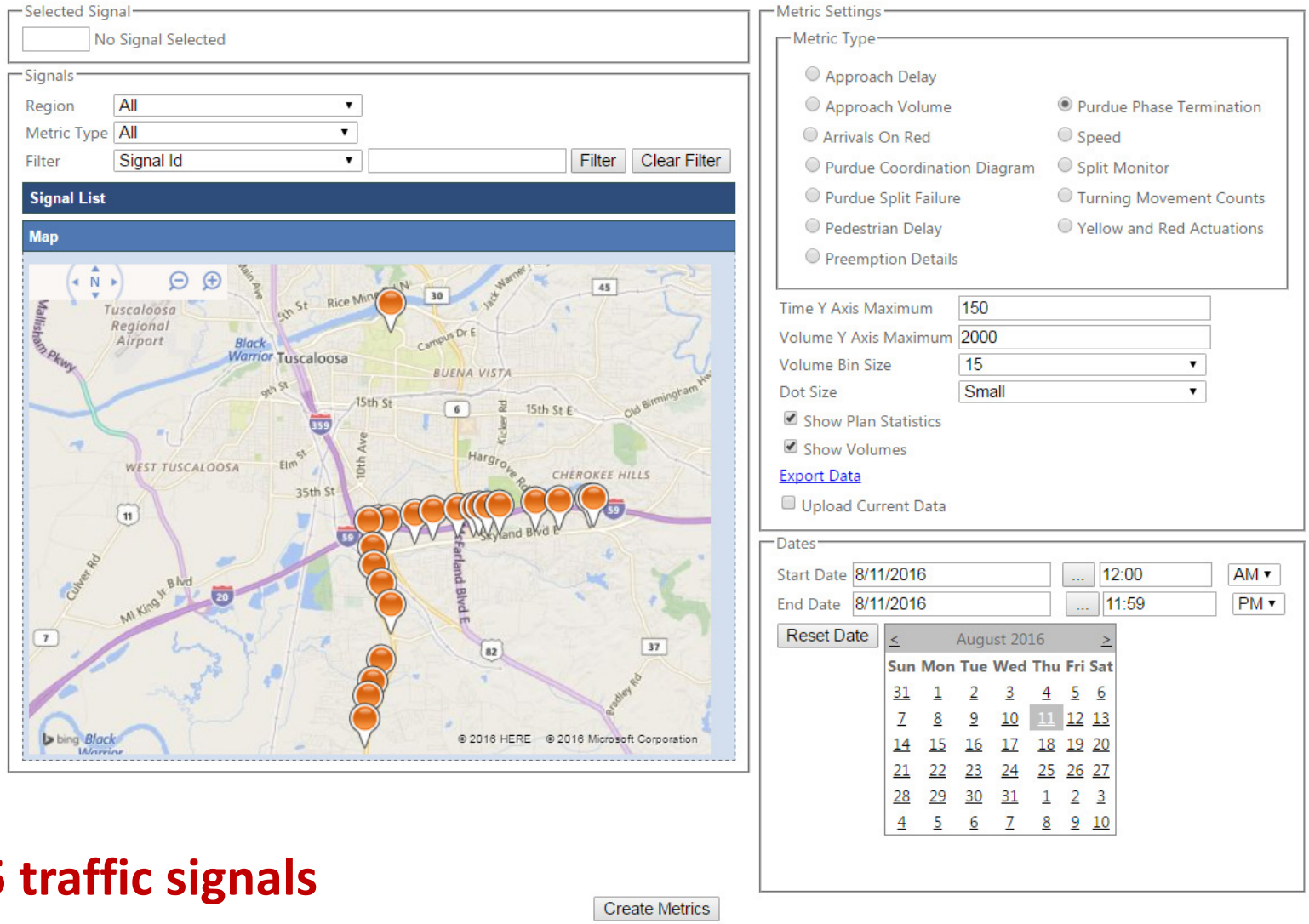
Create Metrics

316 traffic signals

http://signalmetrics.ua.edu

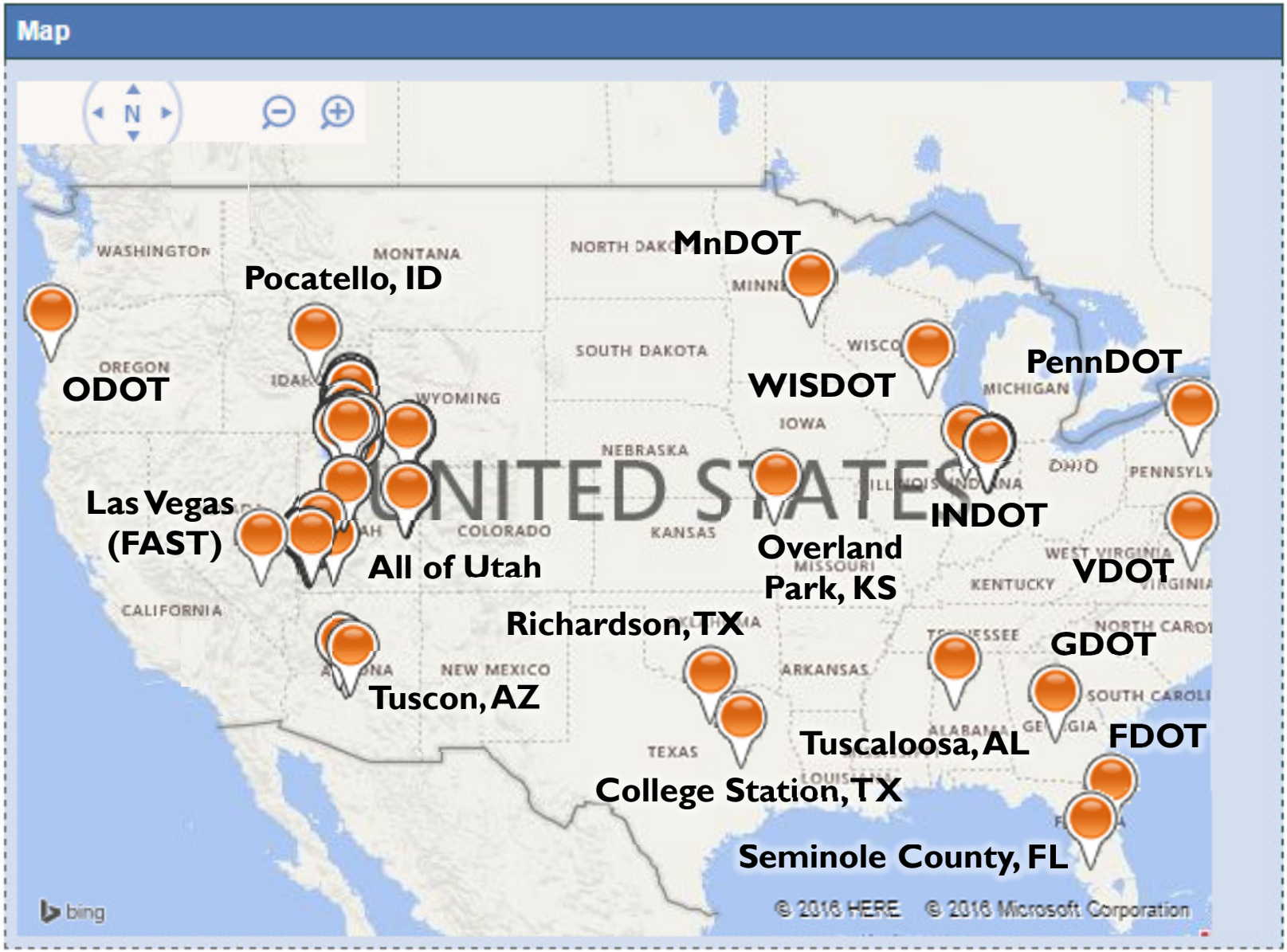
Signal Performance Metrics

->Signal Metrics

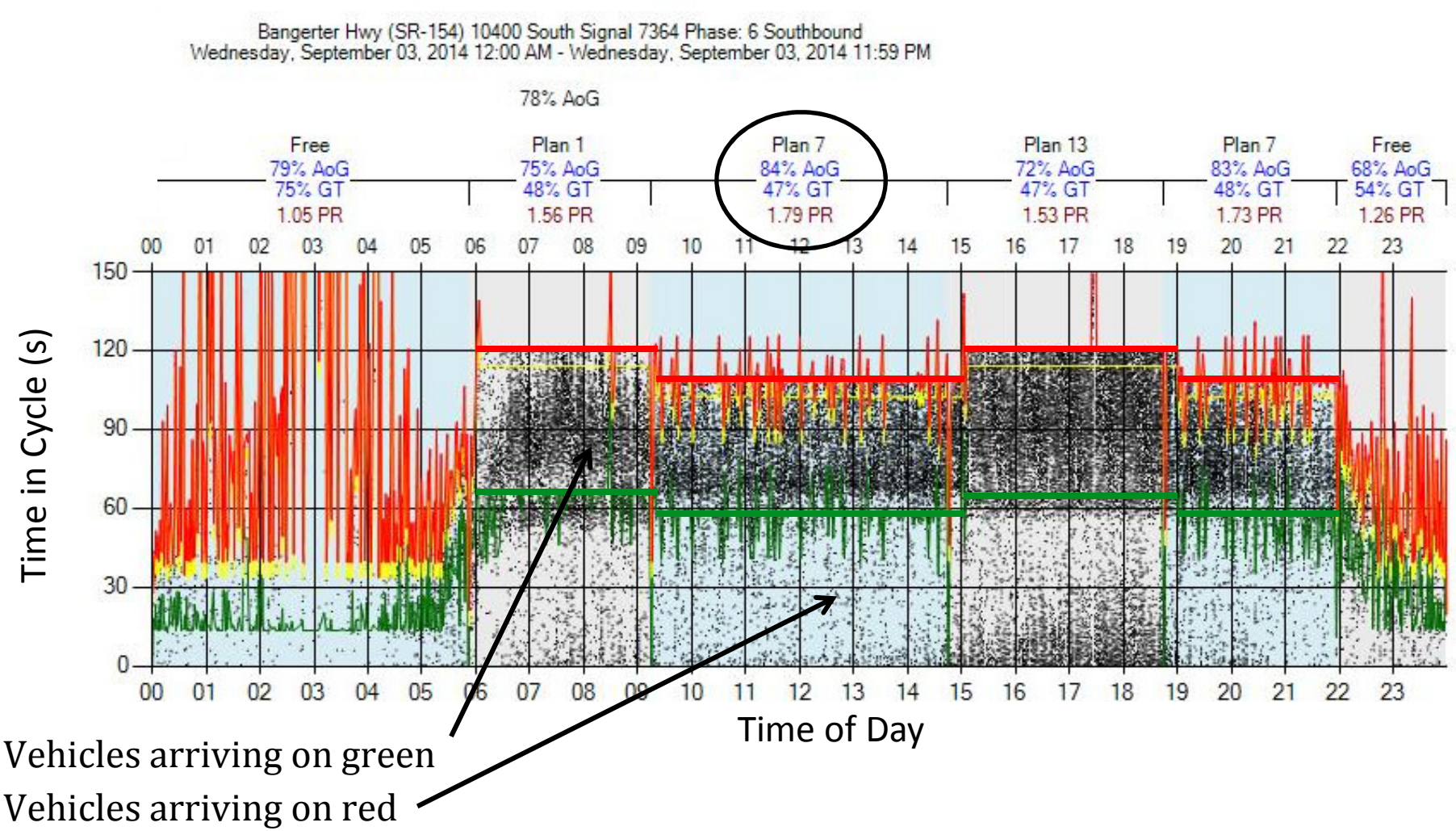


45 traffic signals

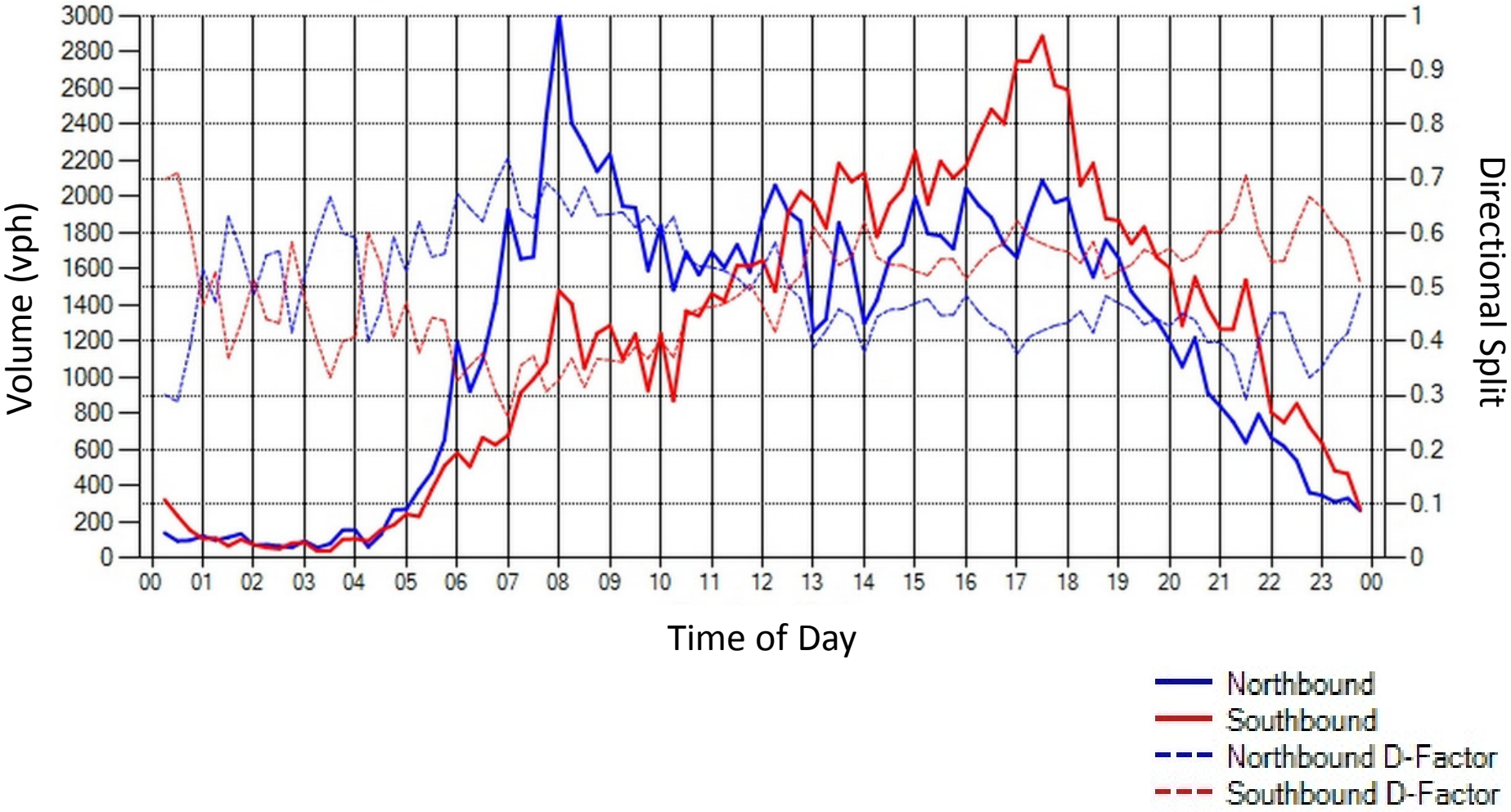
Agencies using SPMs – Separate systems deployed (16 and growing)



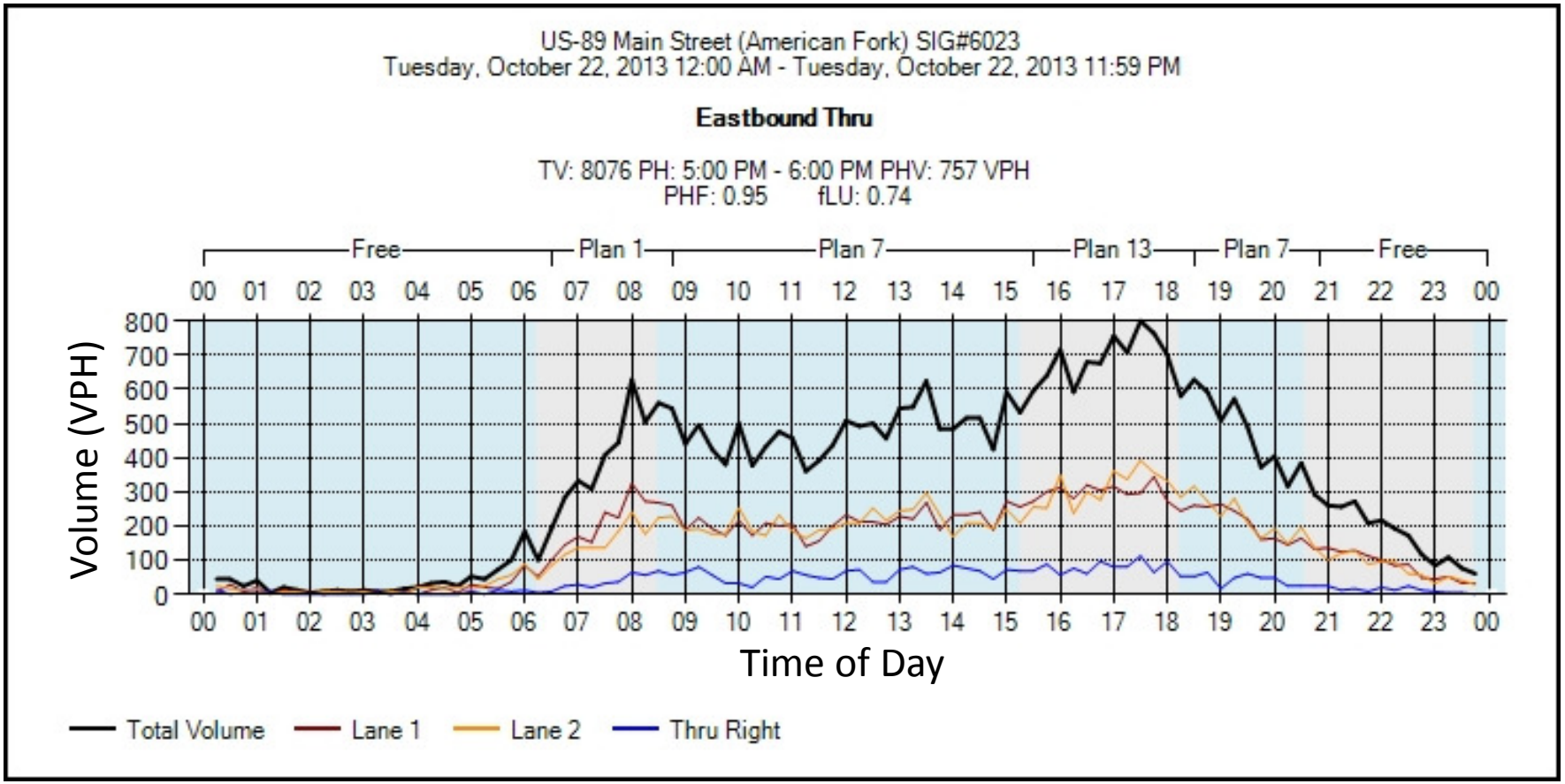
Metric: Purdue Coordination Diagram



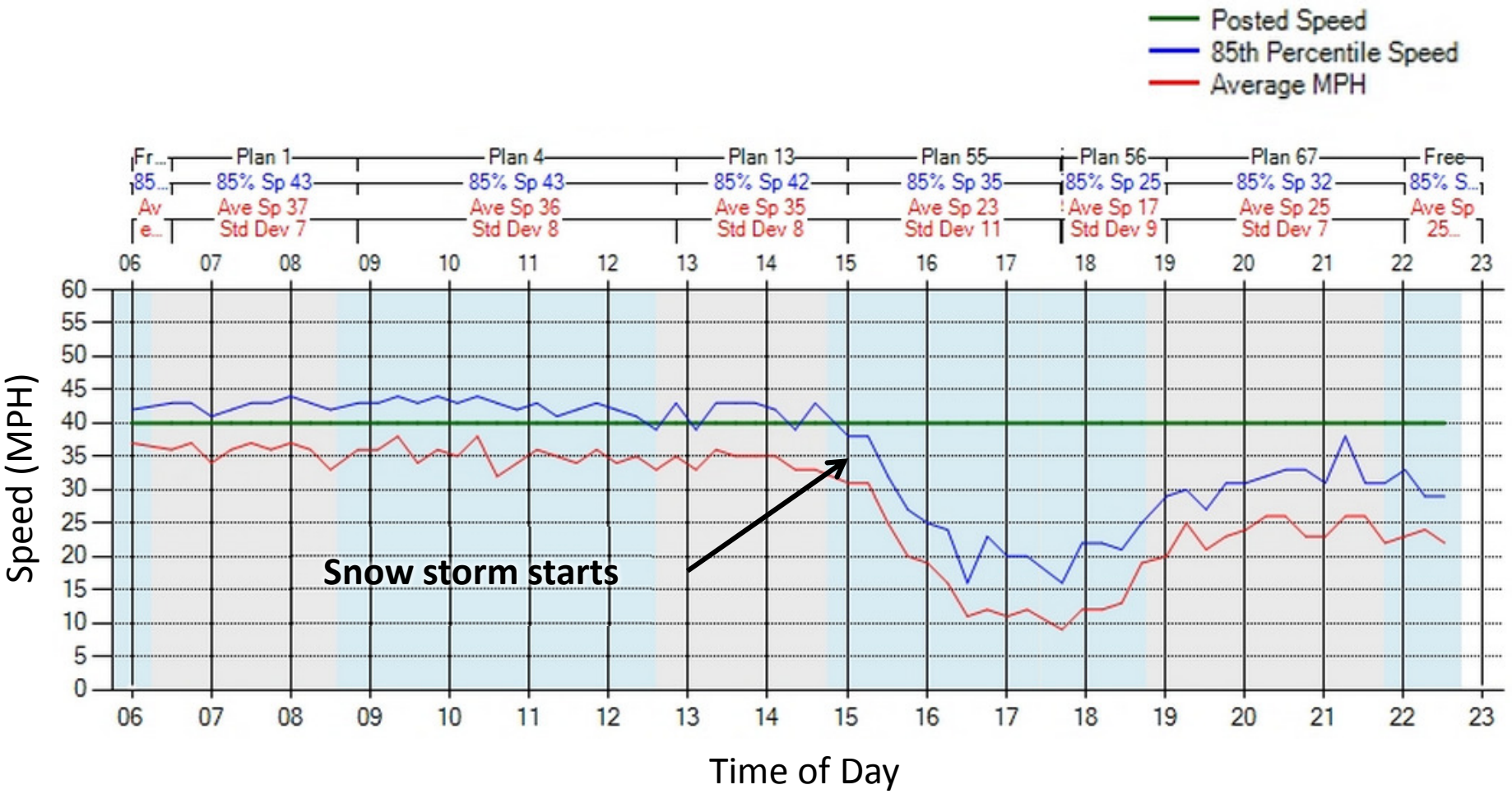
Metric: Approach Volume



Metric: Turning Movement Counts



Metric: Approach Speed



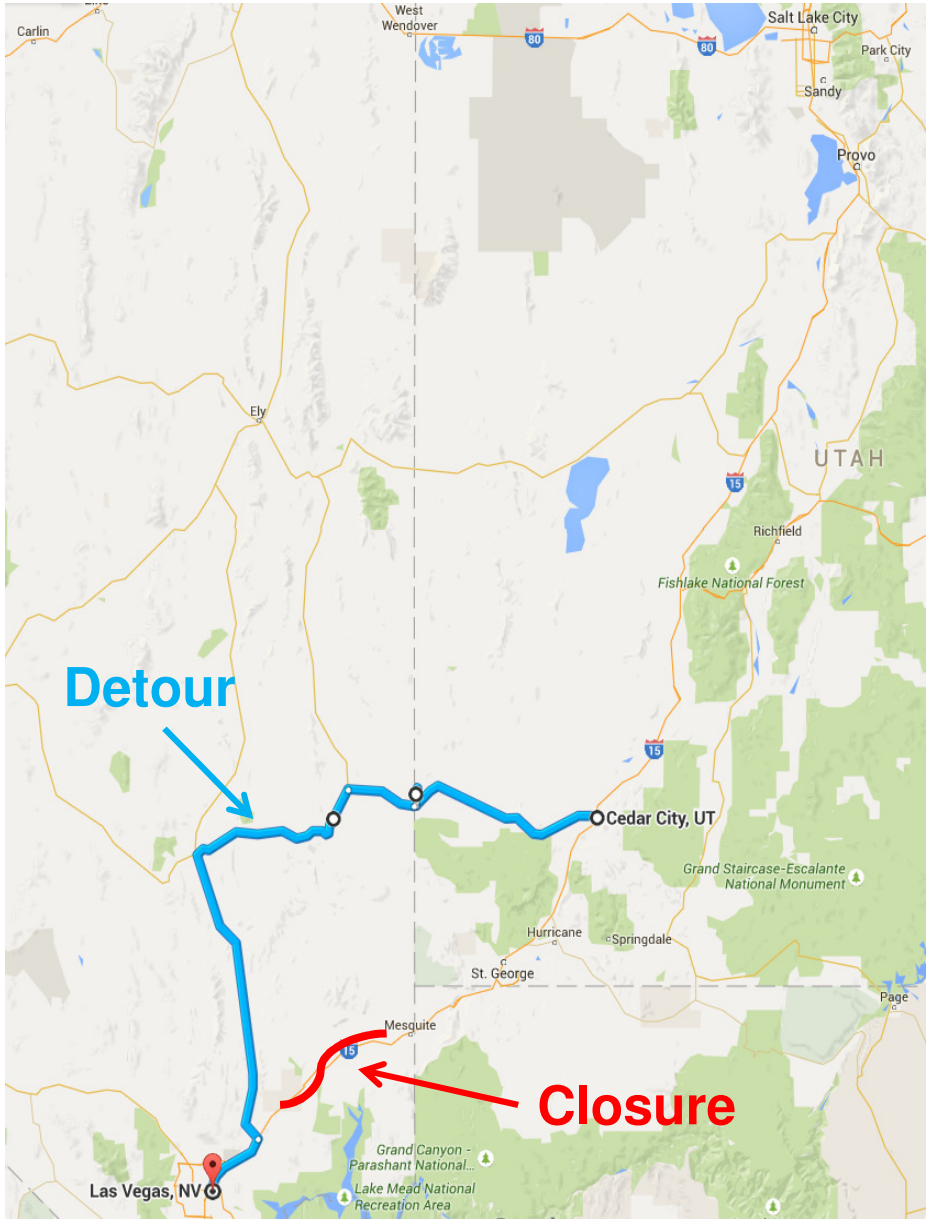
Freeway Closure Example using SPMs - Nevada

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

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


© Reuters

Freeway Closure Example using SPMs - Nevada



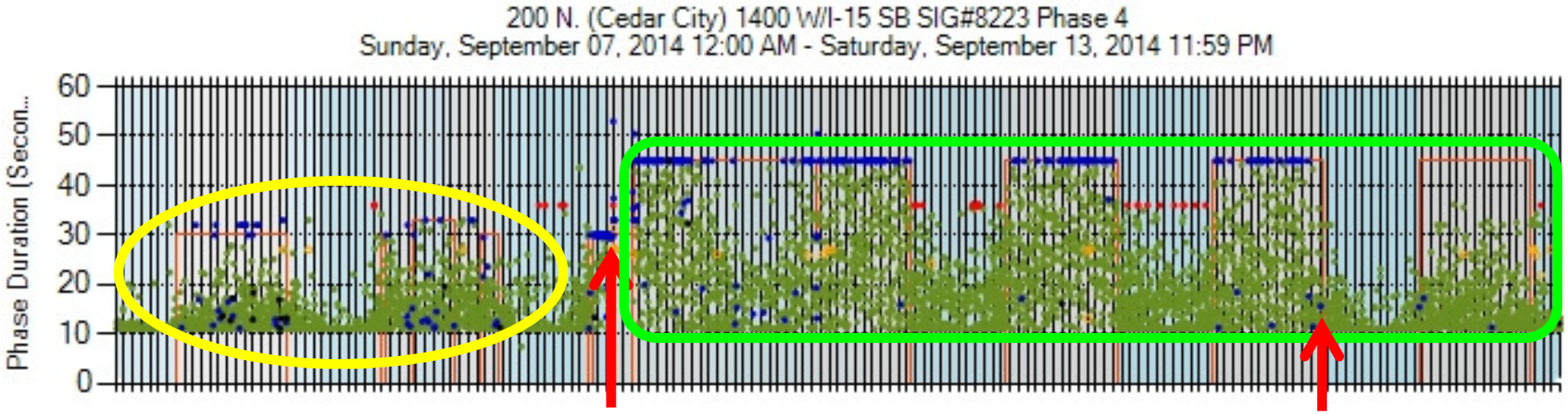
Closure: September 9-12, 2014

I-15 Closed Southbound in Nevada

- 4 day closure
- Detour thru Cedar City to get to Las Vegas.

Phase 4 Split Monitor - (Thru & Left Turn for SB off-ramp)

Freeway off-ramp - One week of data



Normal Traffic on Sunday and Monday

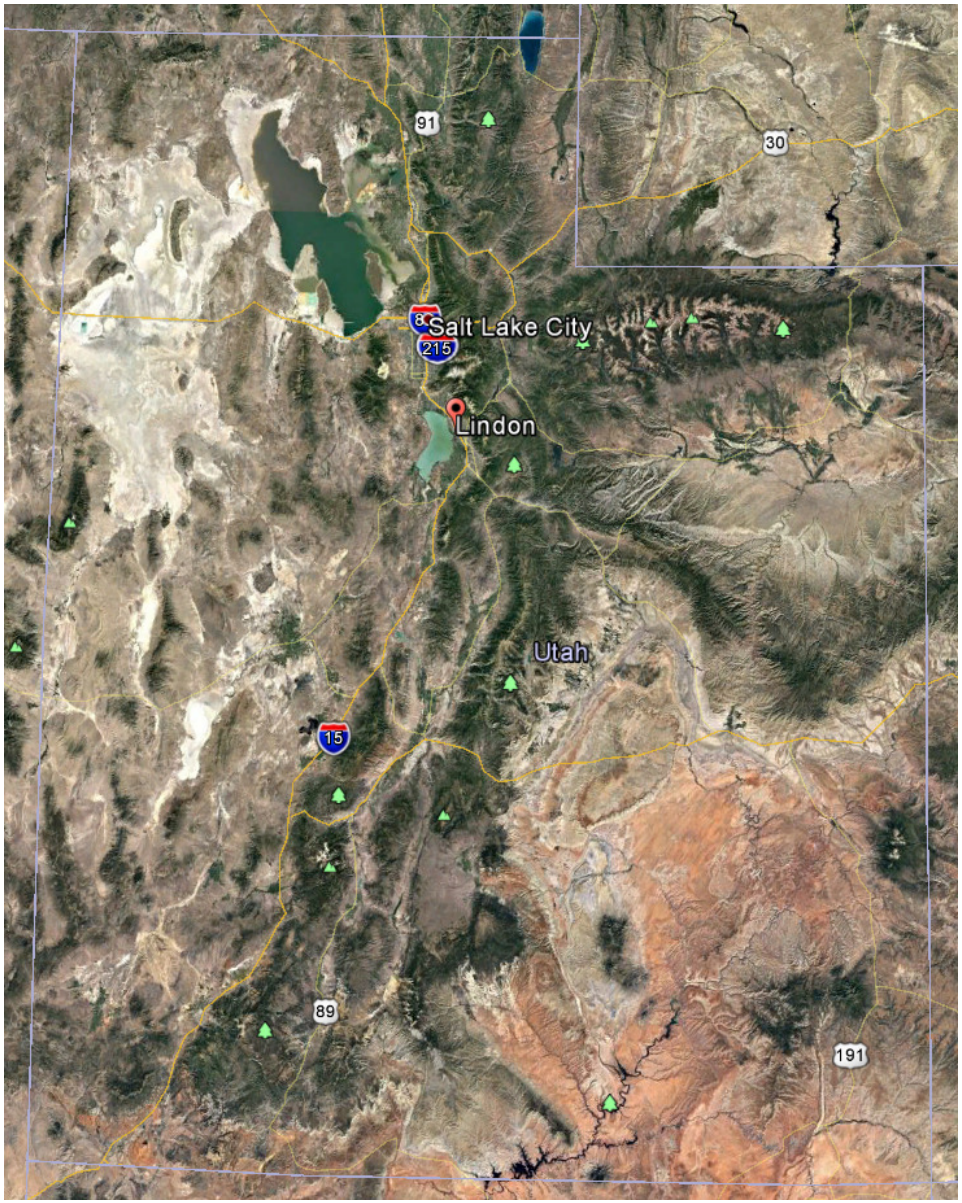
Increased traffic beginning Tuesday morning due to freeway washout in Nevada as shown by more frequent force off and higher split being used

Traffic begins to ease on SB freeway ramp as shown by more frequent gap-out and lower split being used

ODOT implemented on Friday afternoon to provide extra split

- Gap out
- Pedestrian activation
- Max out
- Force off

Railroad Preemption Example – Lindon Utah




City of Lindon, Utah
Geneva Rd
200 South
W 200 S St
114
S 1060 W St
© 2016 Google
Google

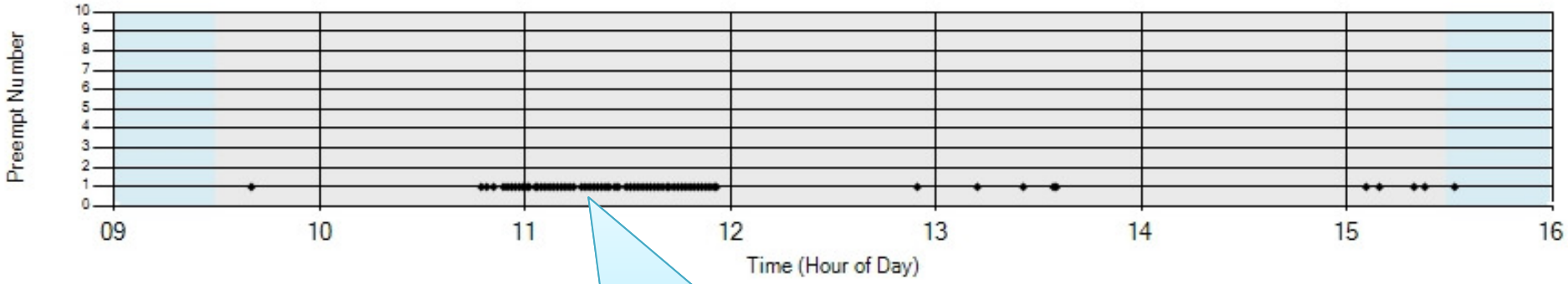

RAIL ROAD
CROSSING
DO NOT
STOP ON
TRACKS
GENEVA RD


City of Lindon, Utah
Geneva Rd
200 South

Preempt Service Chart

SIG#6057 Geneva Rd & 200 S (Lindon)

Wednesday, May 25, 2016, 9:00 AM to 4:00 PM



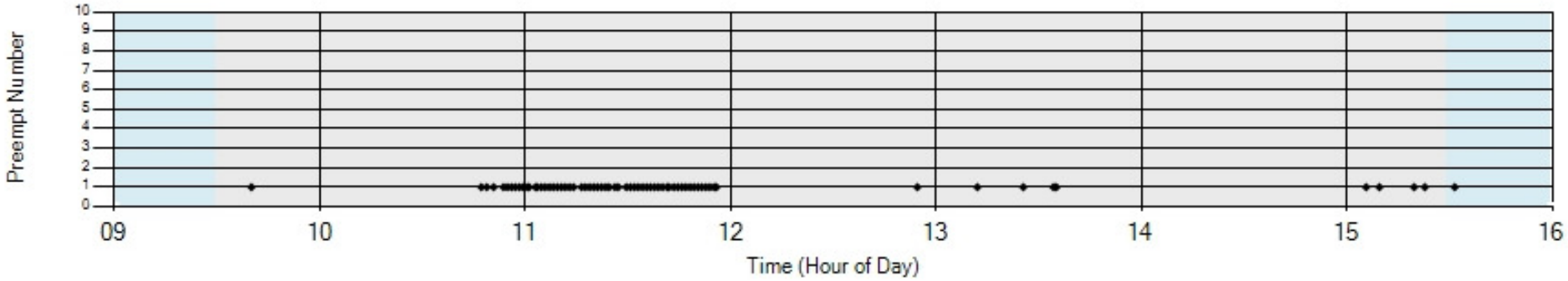
56 Preempt Requests & Services in **70** minutes

Gate down **35%** of the time

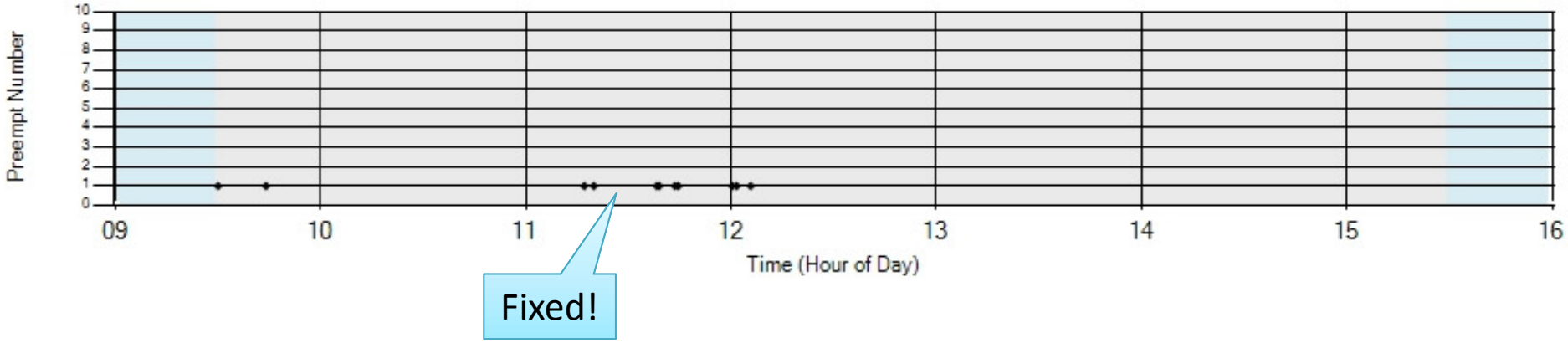
- Train passes through 2x a day Monday, Wednesday, Friday
- Complaints received monthly for a long time. Techs frustrated at this signal.
- Previously, there was no data to provide Union Pacific.

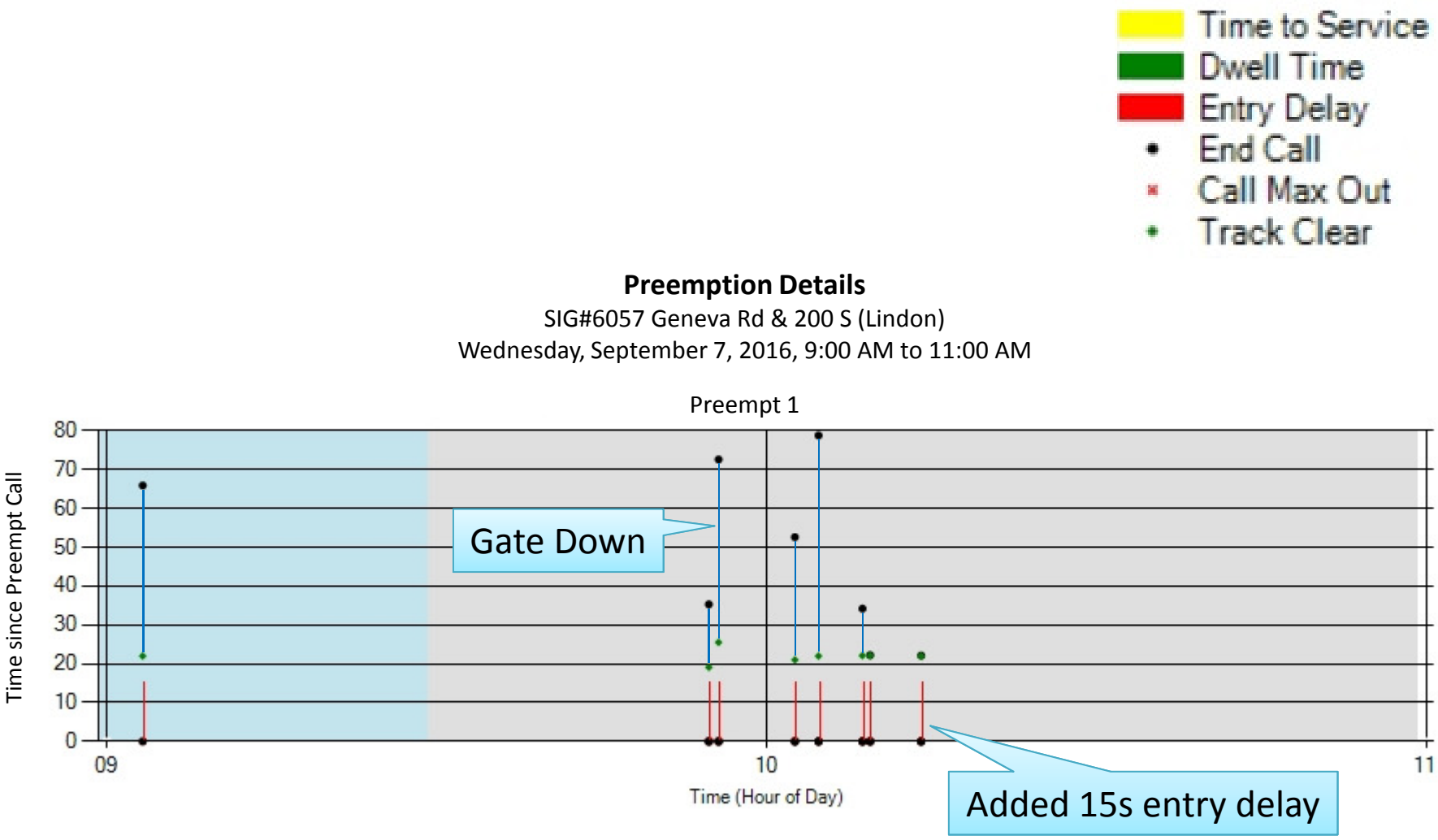
Union Pacific installed some isolation on the spur line where the track switched so the circuit wasn't being falsely triggered

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



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





SPMs also provide information on how long the gate is down. Ono September 7th, it ranged from 18 seconds to 57 seconds.

Outcome Assessment of Peer-to-Peer Adaptive Control Adjacent to a National Park

PURDUE UNIVERSITY

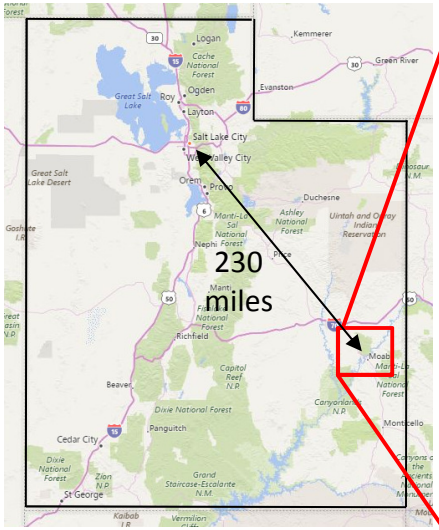
Lucy Richardson
Christopher Day
Darcy Bullock

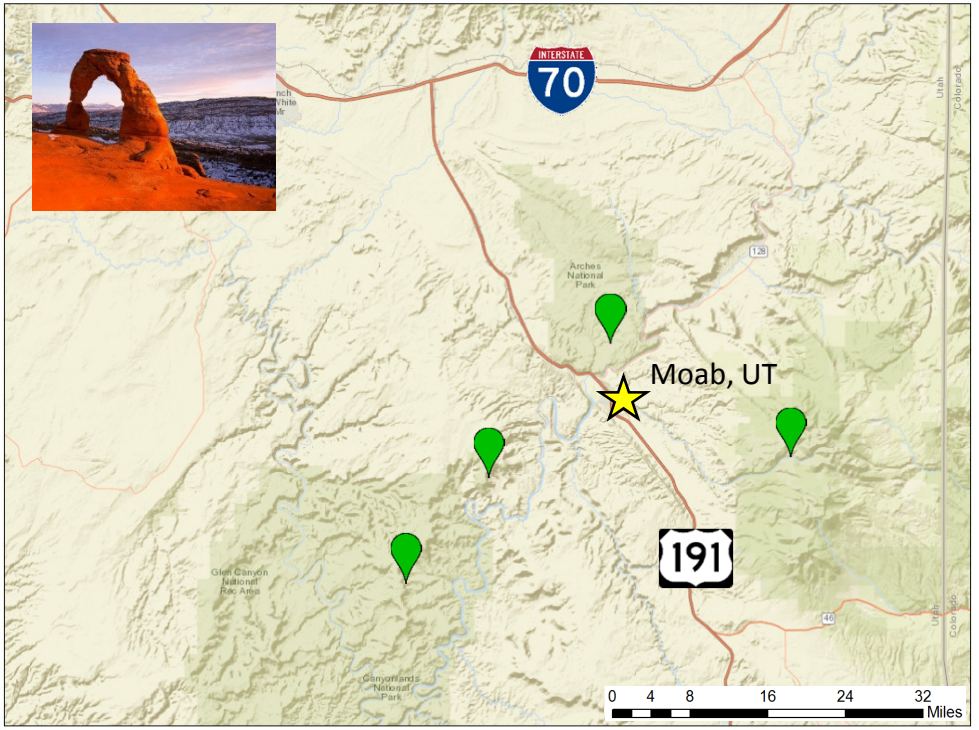
UDOT Keeping Utah Moving

Matthew Luker
Mark Taylor

Arches National Park @ArchesNPS · May 28

A view of the Arches entrance line. Cars are lined up onto US 191. (cw) #archesnps #archesnationalpark

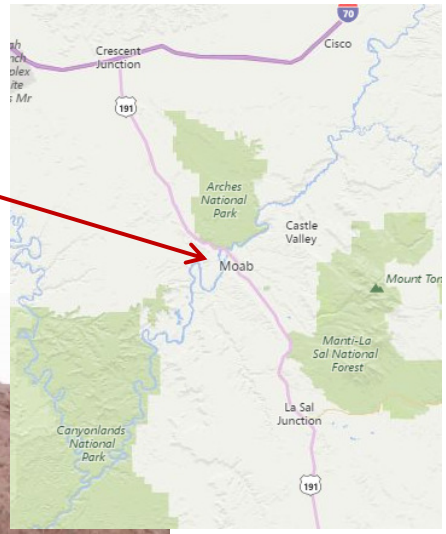




Recreational Area

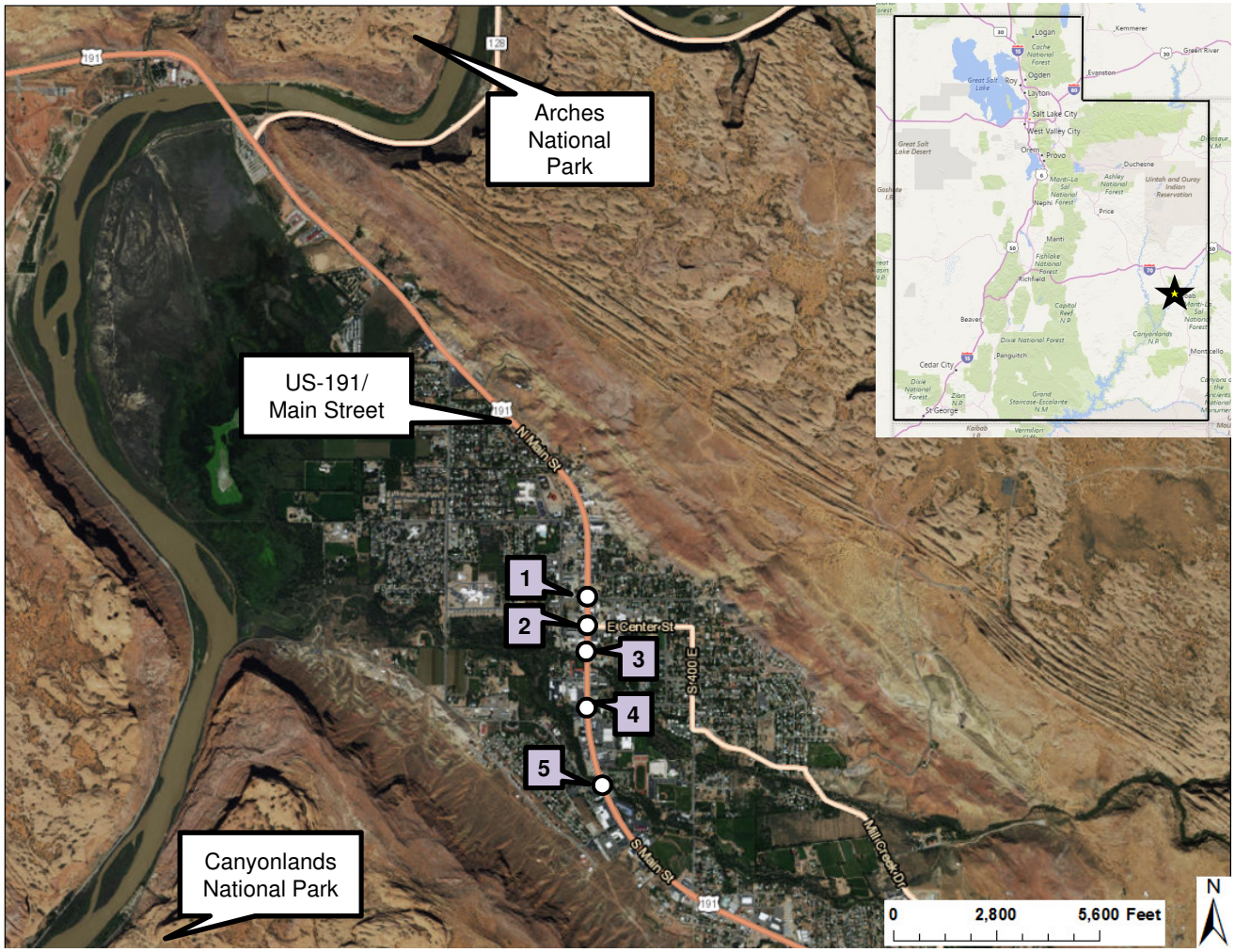
Case Study: Moab, Utah

- The Adventure Capital of the U.S.A.
- Two National Parks within 20 miles



Corona Arch & Balanced Rock - Moab

Unpredictable Traffic – Very Seasonal



Keeping Utah Moving

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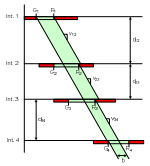
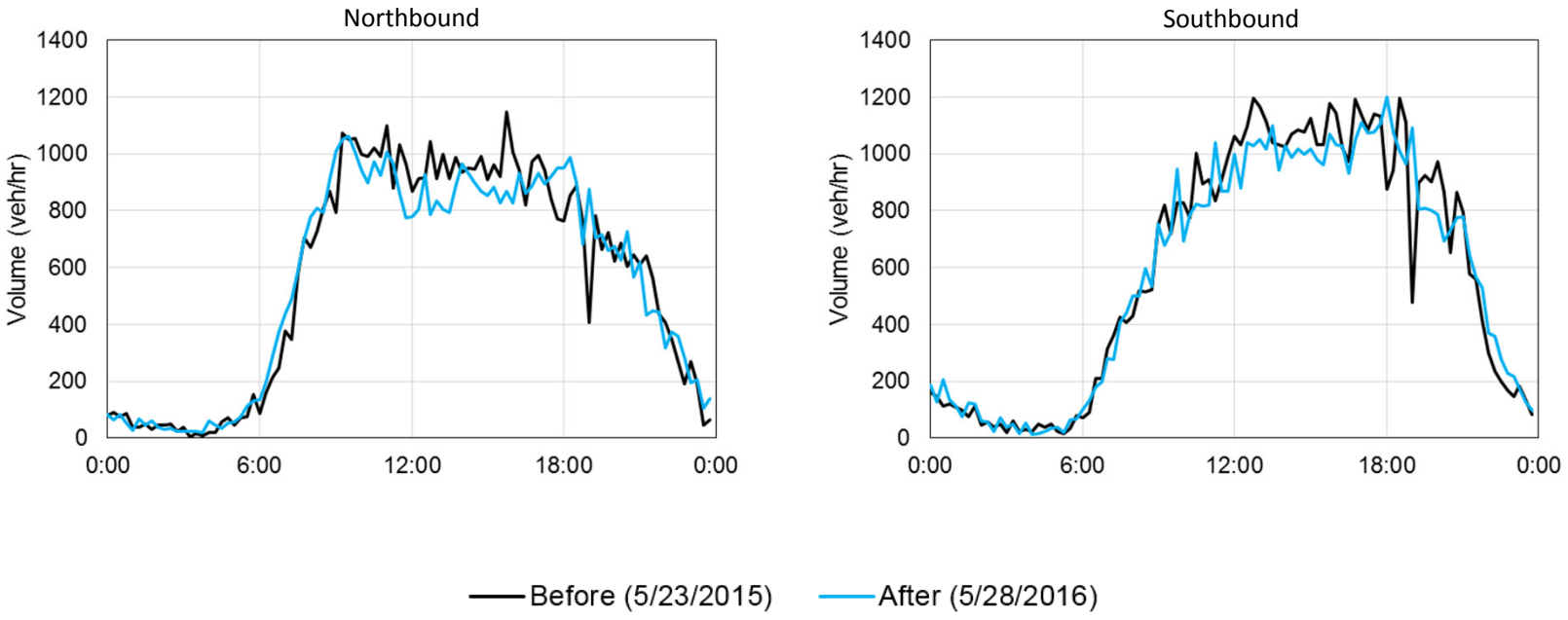
Memorial Day 2015 vs. 2016

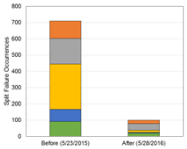


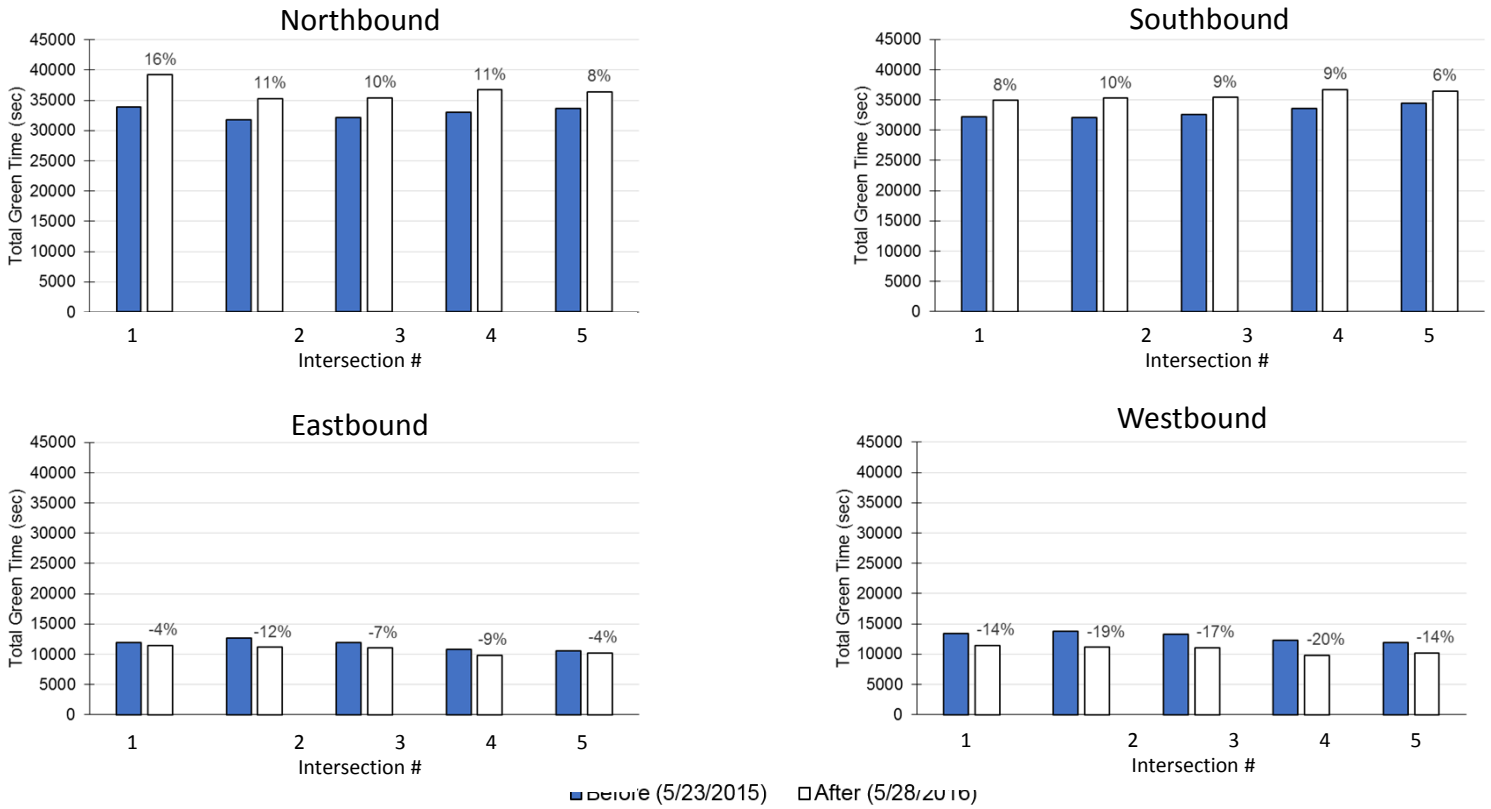


UDOT Keeping Utah Moving

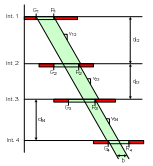
PURDUE UNIVERSITY

Allocation of Green Time





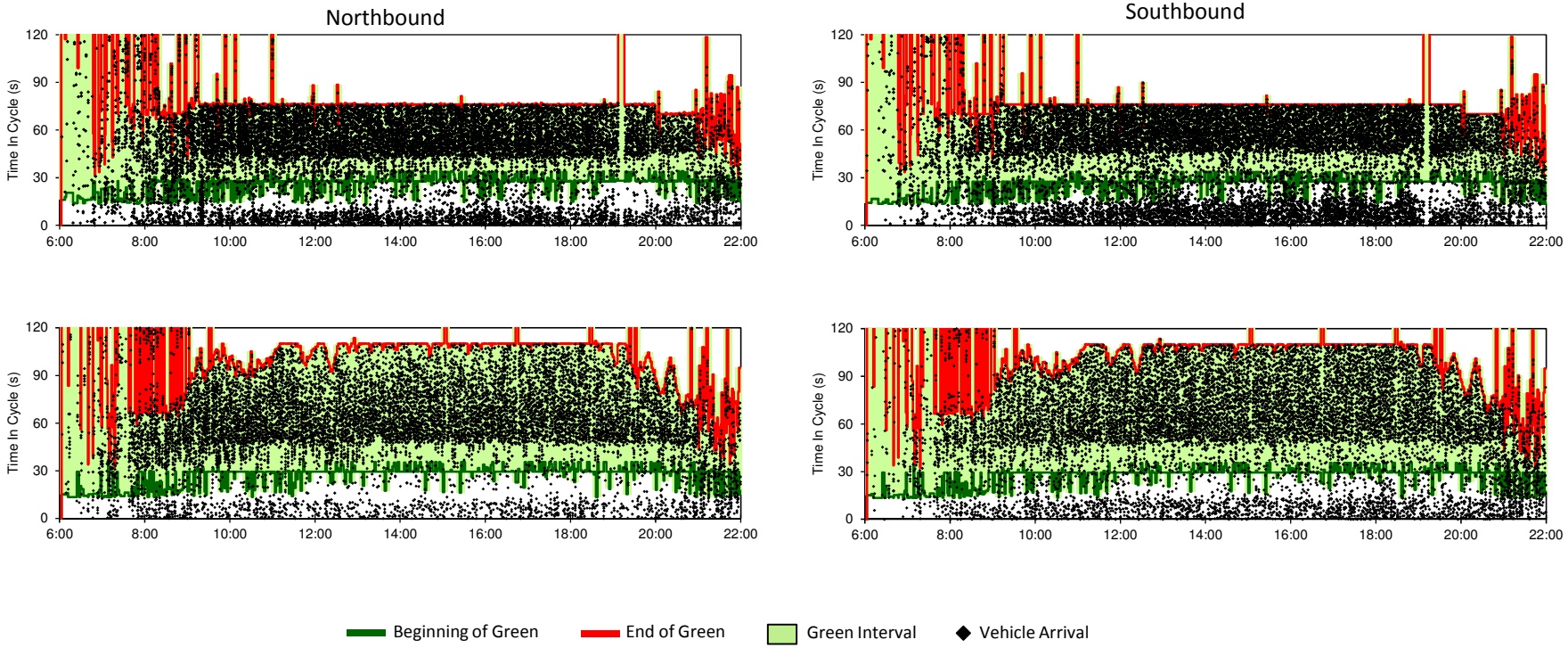
Corridor Progression: PCDs



Memorial Day

Before
2015

After
2016



Keeping Utah Moving

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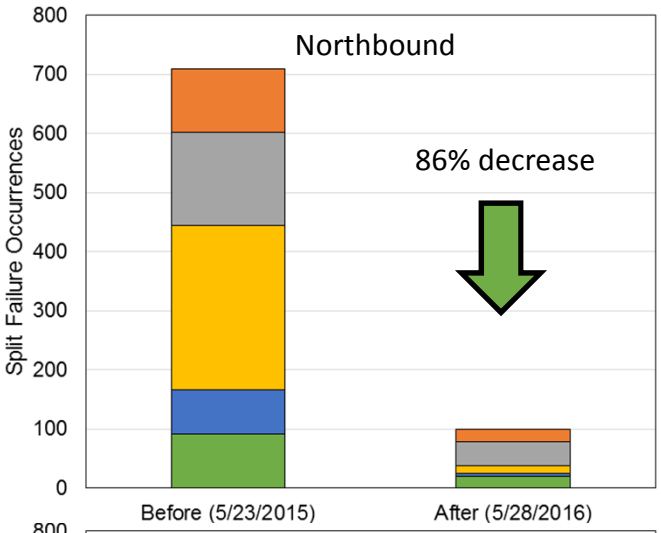
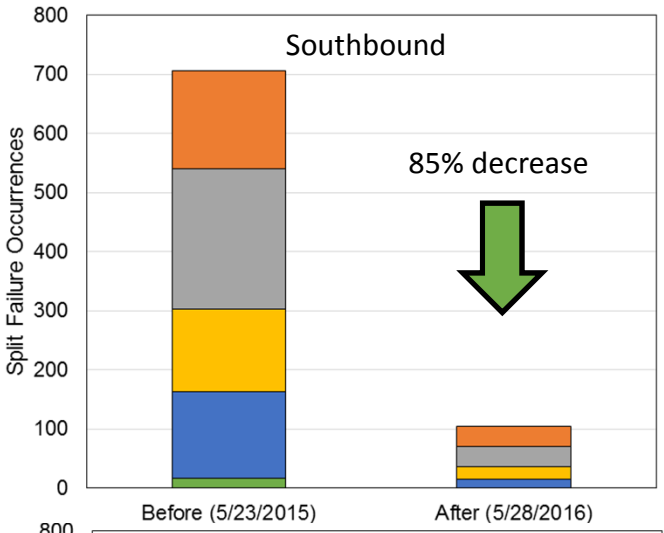
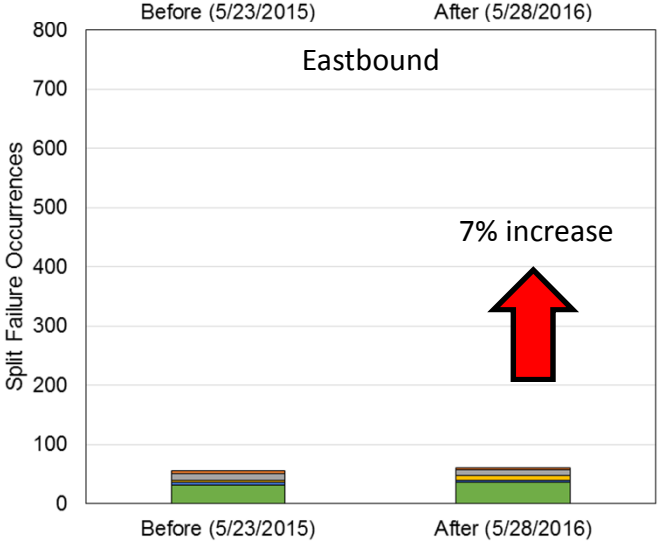
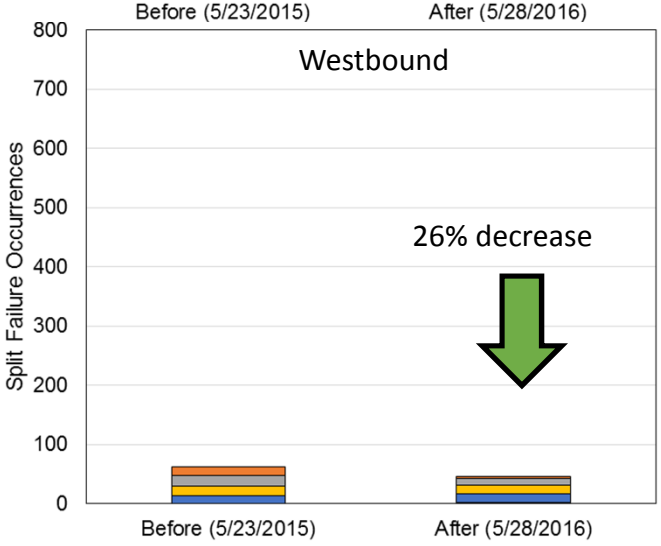
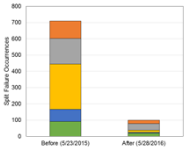
Moab – Split Failure Results



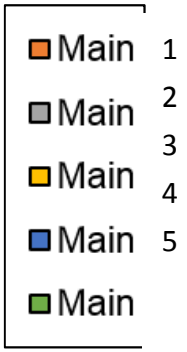








Intersection #



UDOT Keeping Utah Moving

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System Health

1. No SPM Data
2. Too many max outs
3. Too many force offs
4. Too many ped calls
5. Low PCD detector count
6. High PCD detector count

1710 traffic signals

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)

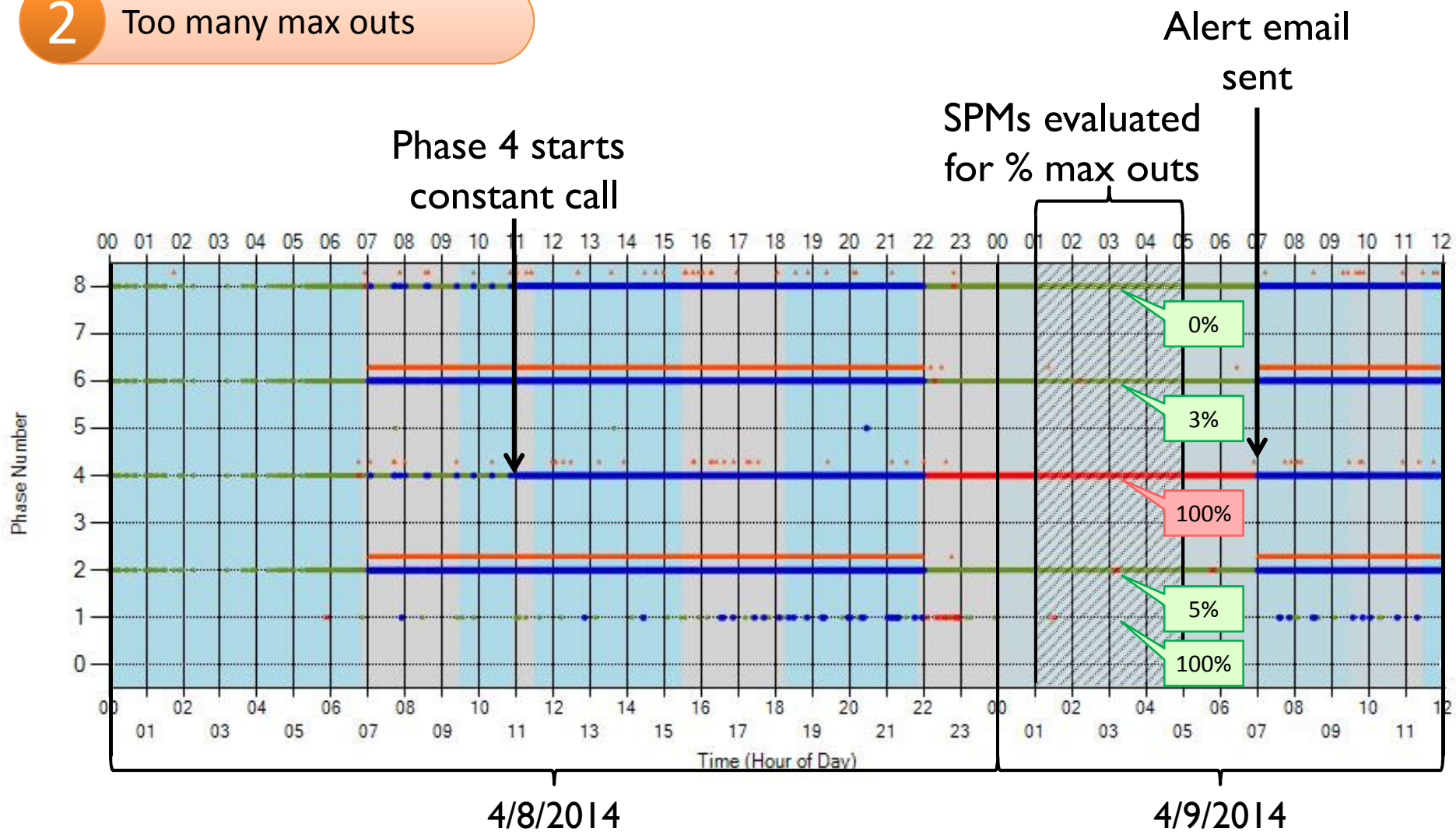
--The following signals had too many force off occurrences:
1224 - North Temple & Main Street - Phase: 3 (Force Offs 97.6%)
7252 - 500 South & Main Street - Phase: 2 (Force Offs 100%)
7252 - 500 South & Main Street - Phase: 6 (Force Offs 100%)

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

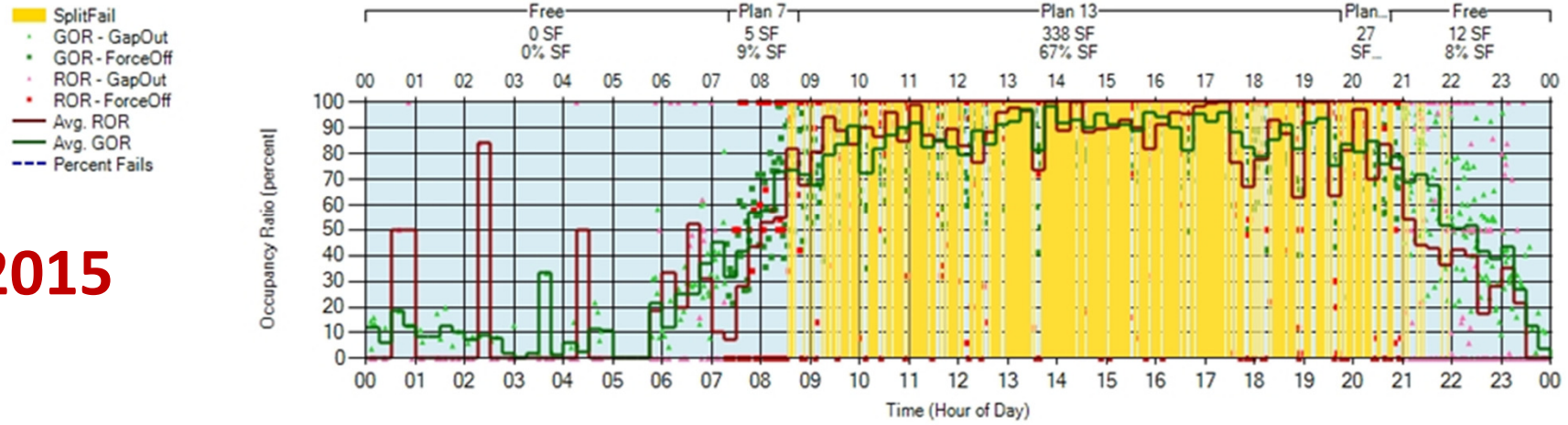
Metric: Purdue Phase Termination
Detection Requirements: None

Purdue Split Failure – Center St & Main St – Moab, Utah

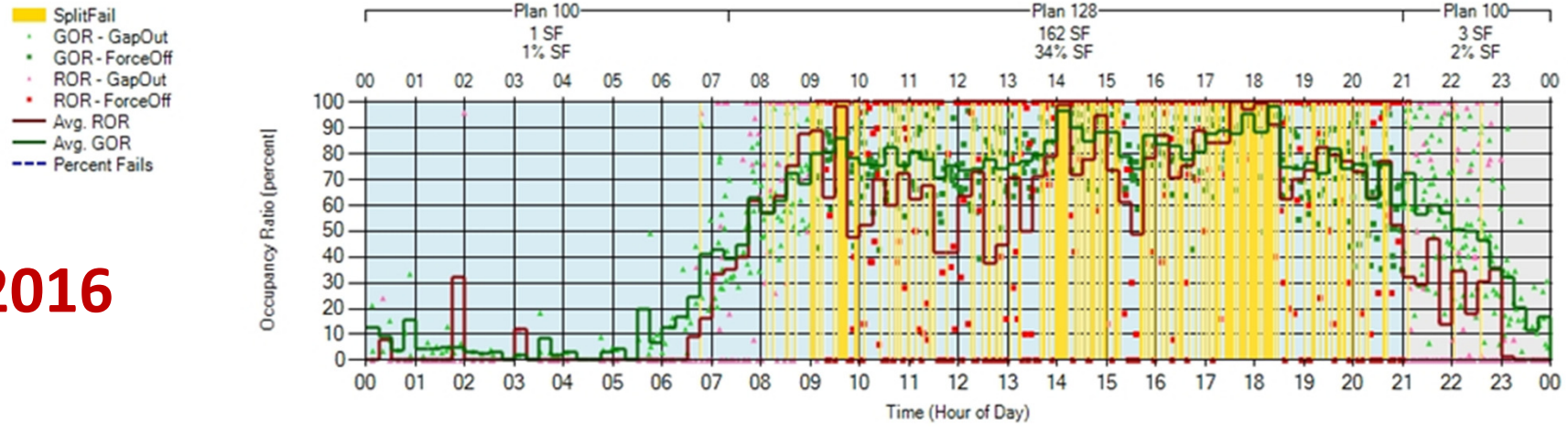
Memorial Day Weekend – Saturday

NORTHBOUND

2015



2016



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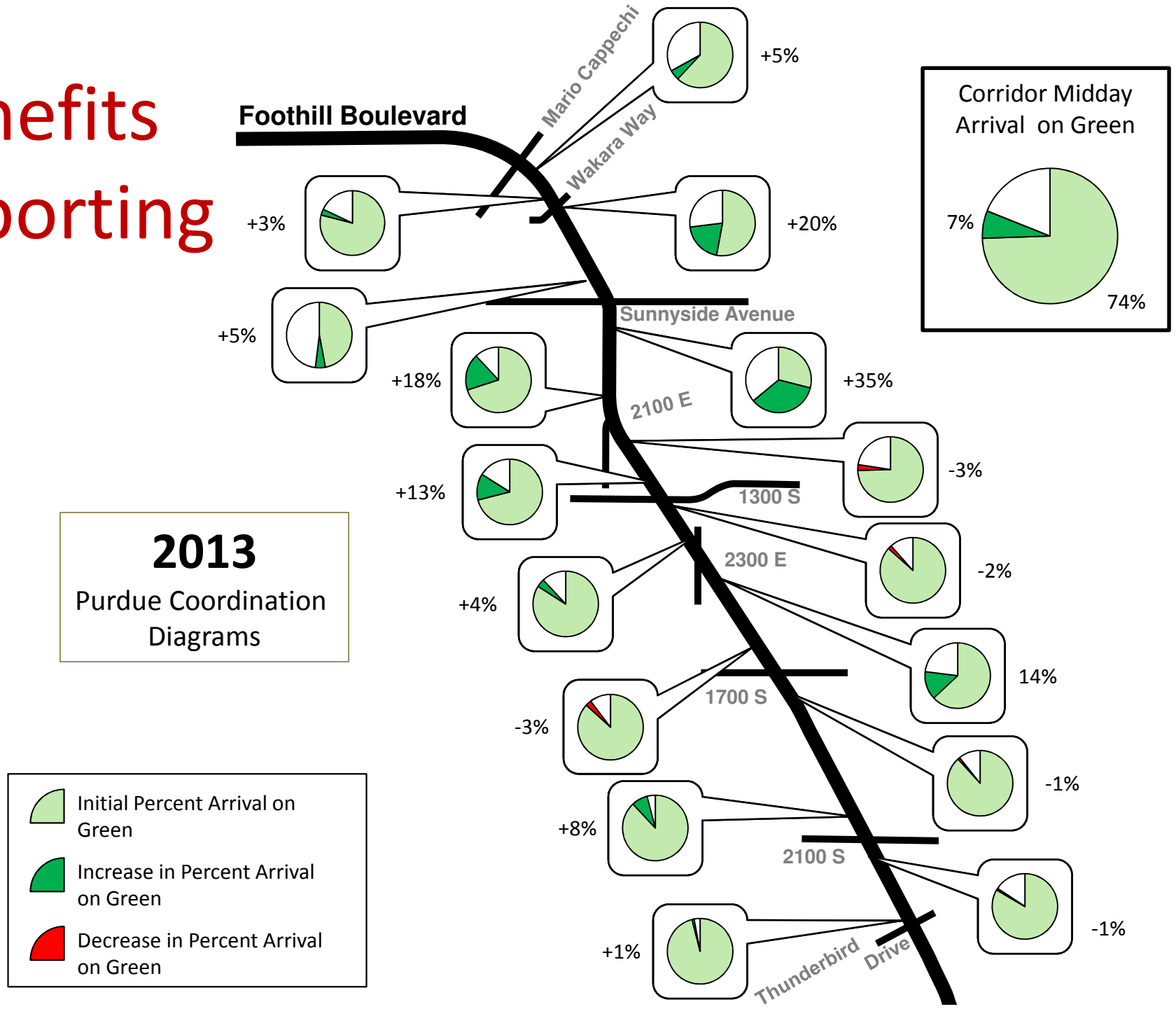
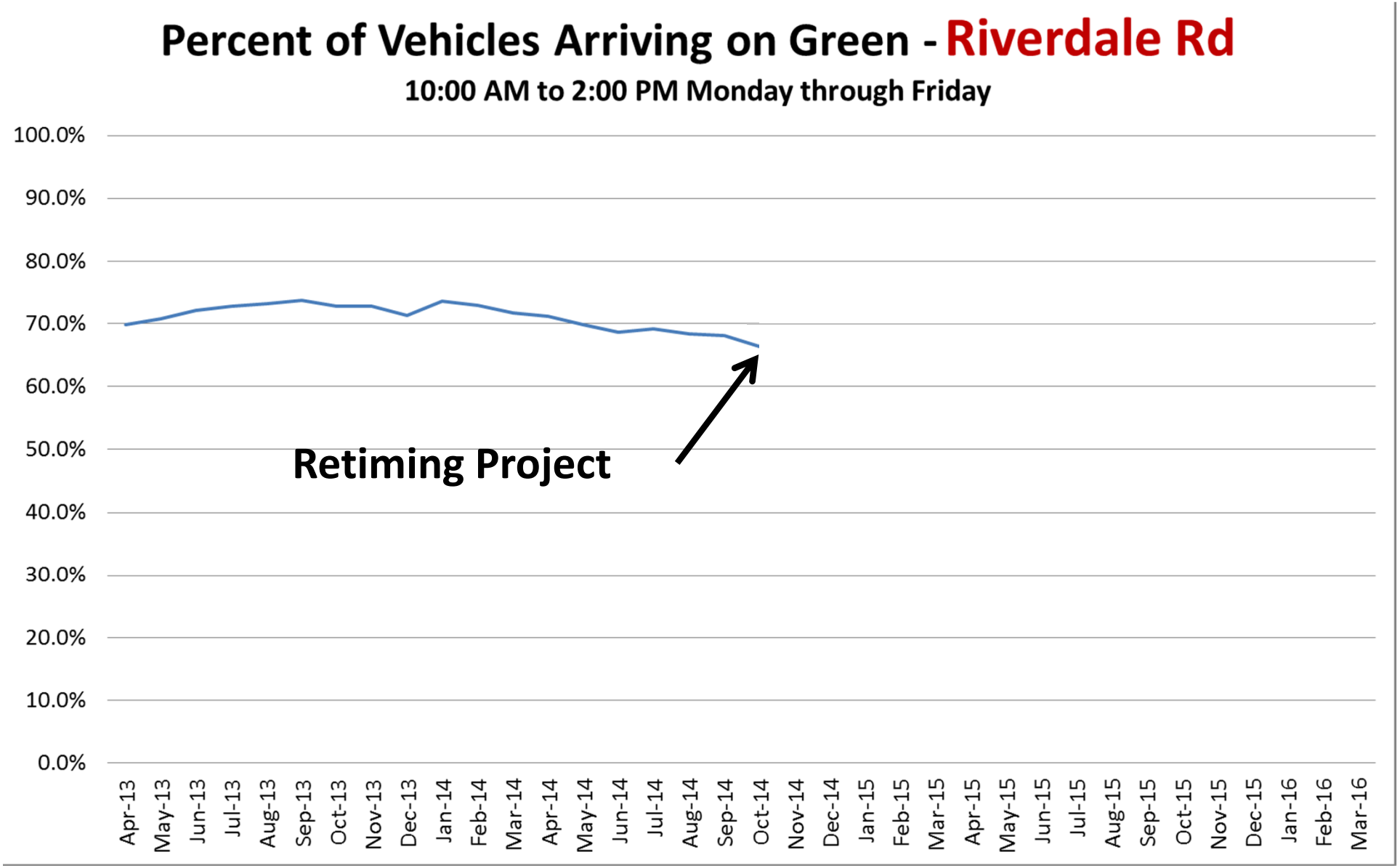
Benefits Reporting

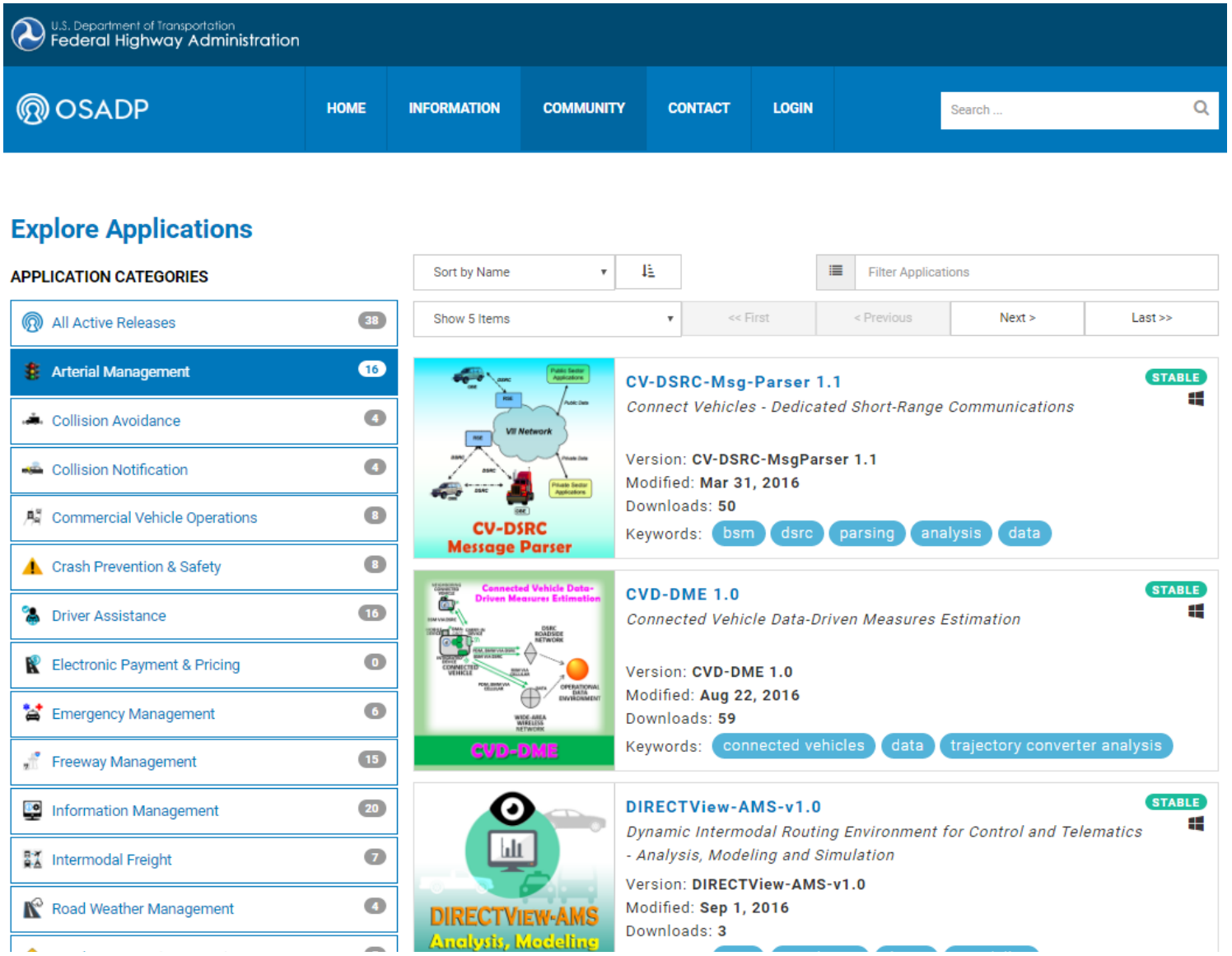


Monitor Trends



SPM Source Code –> Open Source

Mid Nov. 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

Train the Trainer Workshop

When: Salt Lake City: January 18 & 19, 2017

For Whom: Consultants, Vendors, IT Personnel

Learning Objectives: Installing UDOT ATSPM Source Code, Server/Network Requirements, Configuration, Q&A.

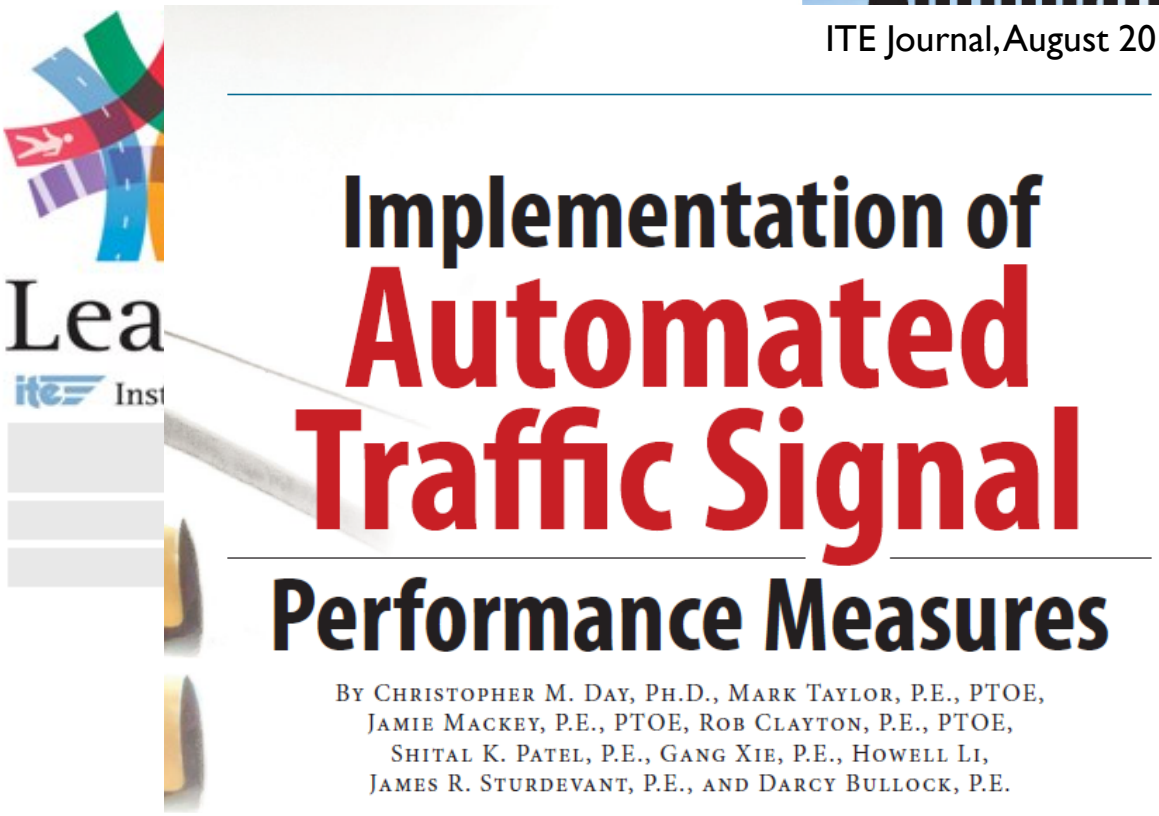
Register: https://www.eventbrite.com/e/udot-train-the-trainer-workshop-for-atspm-tickets-28563394883?aff=es2

Attendance is free.

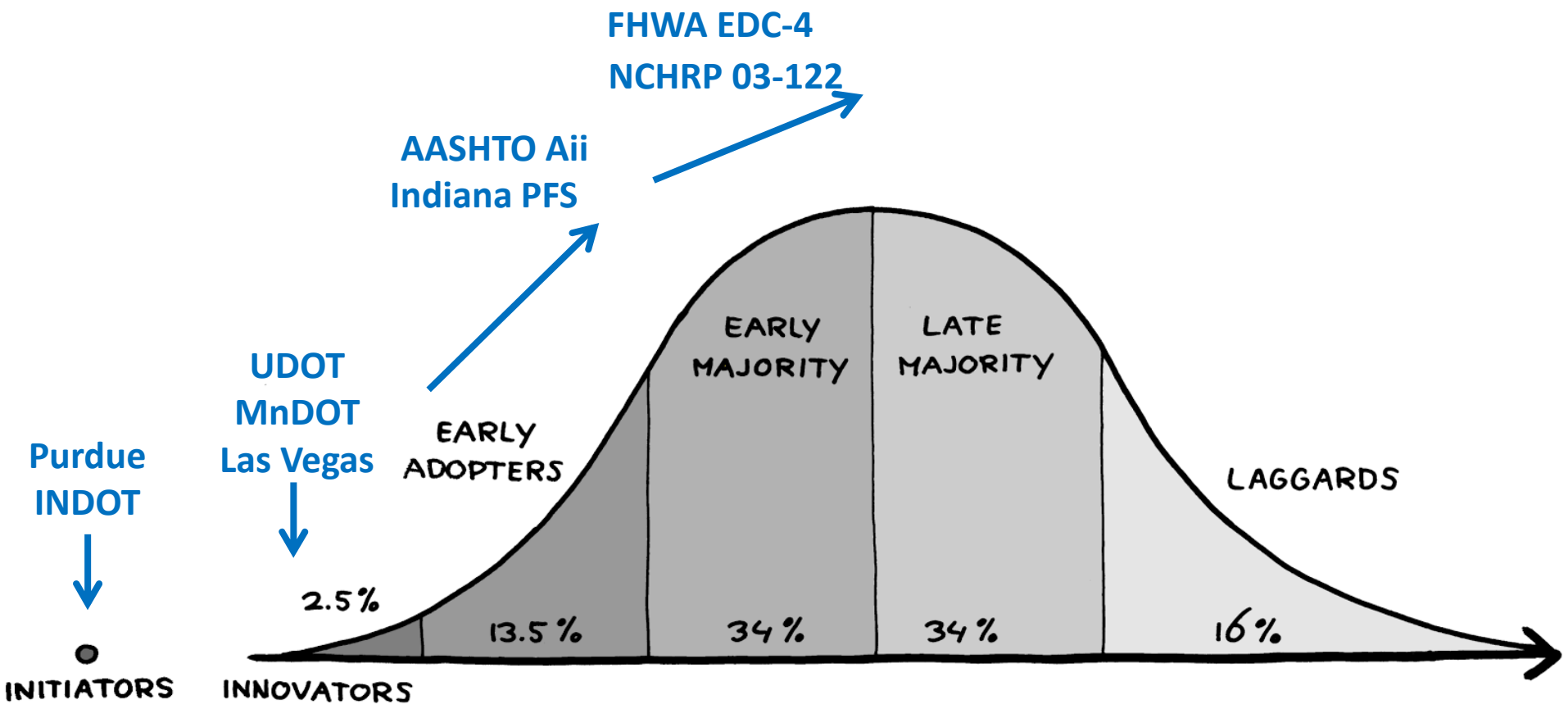
ITE 3-part Webinar
April, May, June 2014

ITE Journal, March 2014

ITE Journal, August 2016



Innovation/Adoption Curve

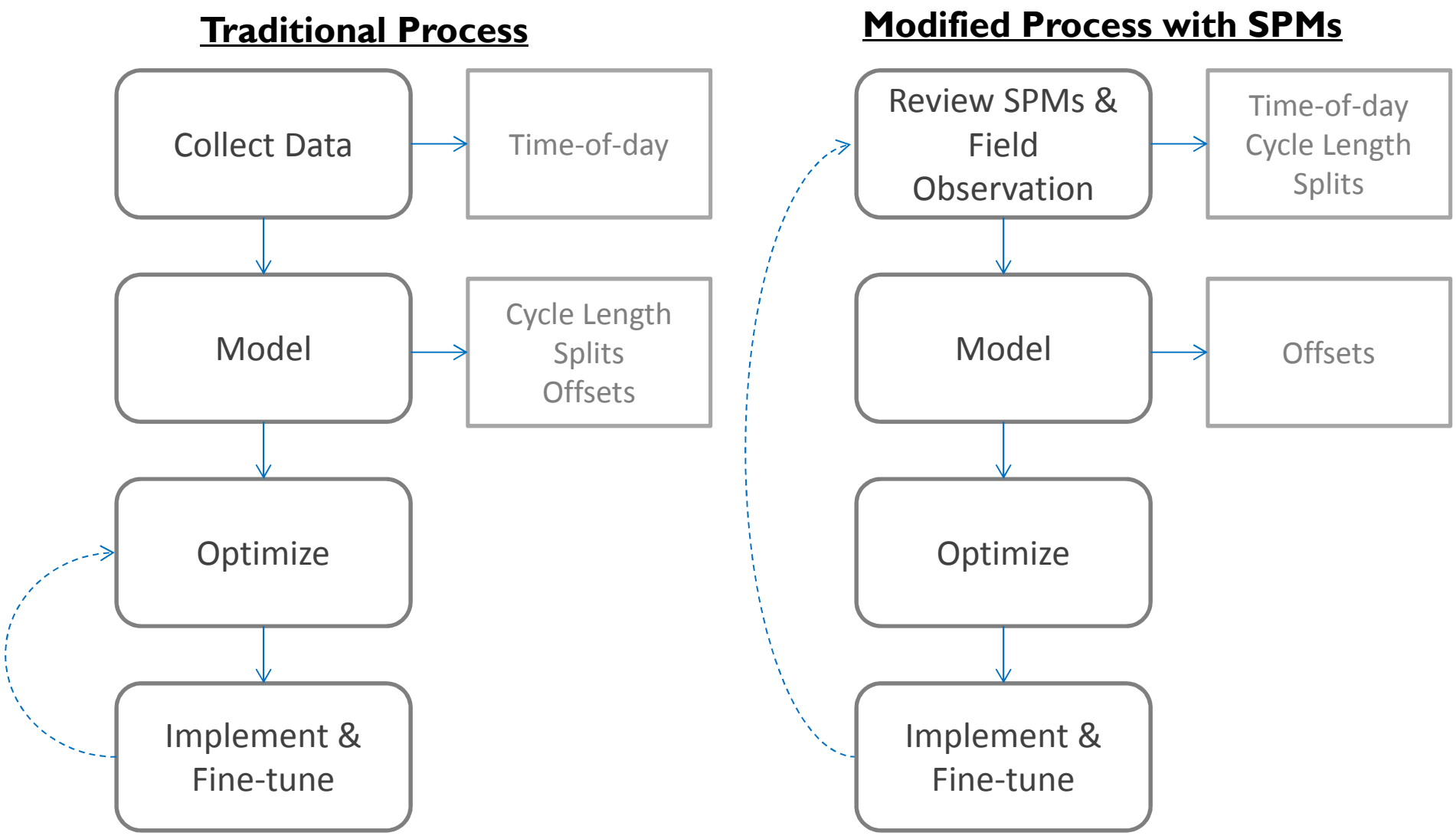


What does it take to get ATSPM's?

- Controller with Purdue hi-res data
- Comm to intersection or external memory (Raspberry Pi)
- Server
  - Price ranges from $3K to $20K (UDOT: $15K on a 20 TB server)
- SQL Database License: Free (Express) to $100K (Enterprise)
- ATSPM Software: Free: (http://www.itsforge.net/)
- Consultant to do installation: $5K to $10K

Total Price for ATSPM's: $3K to $130K+

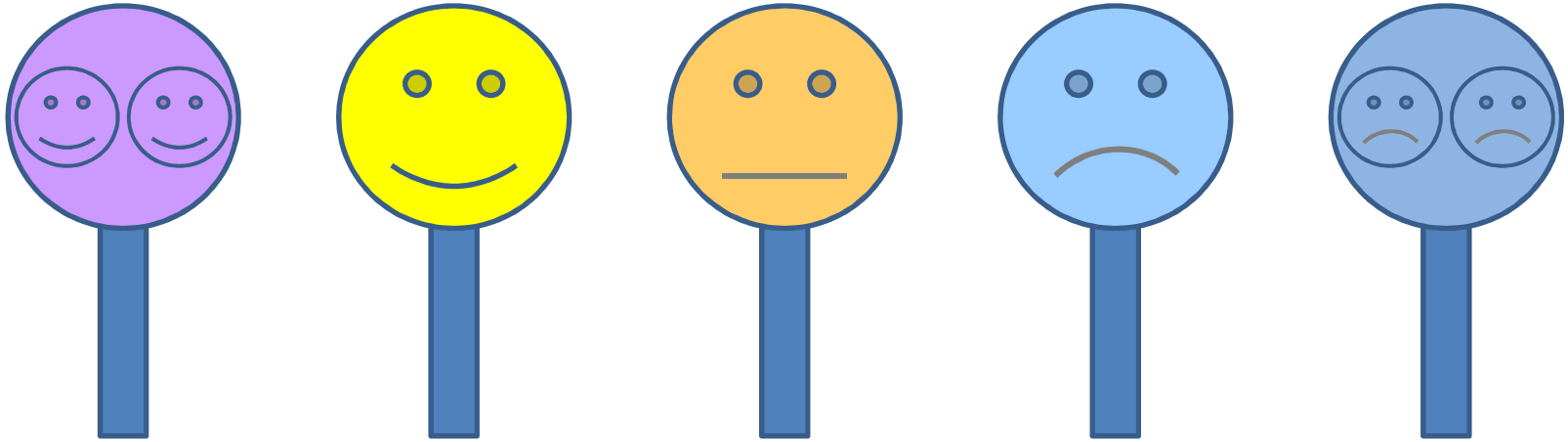
Optimization with SPMs



UDOT Signal Timing Focus Group (July 2014)

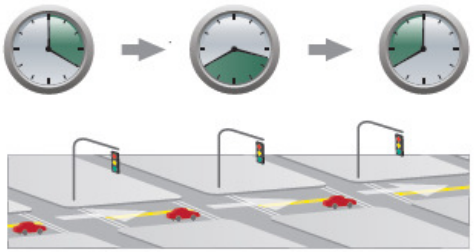
- *How do you feel about UDOT?*

- *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.

60 S Commercial –
Love green lights? So do UDOT traffic engineers

http://udot.utah.gov/greenlights

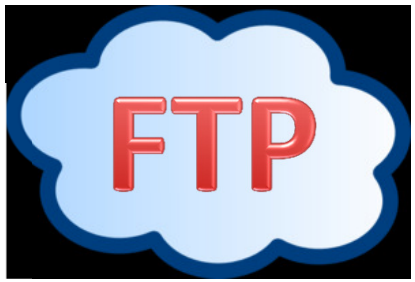

udottraffic.utah.gov/signalperformancemetrics
Mark Taylor
marktaylor@utah.gov
UDOT
Keeping Utah Moving

ATSPM Basic Concept

Hi Def Data Logger included in controller firmware

Hi Def logs retrieved every 10-60 minutes from controller to server

Website to display SPM's



(Or…Retrieve data logs from controller manually using Raspberry Pi)

A Central Signal System is NOT used or Needed!

Why Model what you can Measure?