

# Automated Traffic Signal Performance Measures

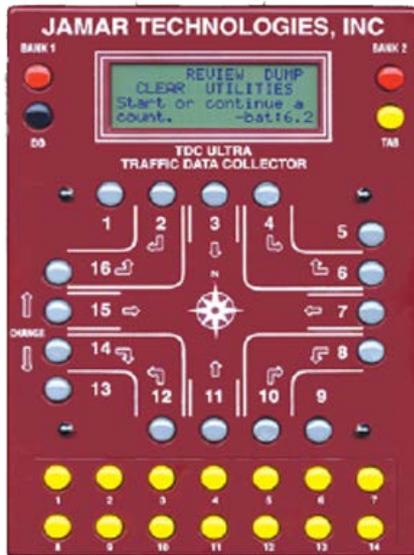


**Penn State Transportation Engineering & Safety Conference  
December 6, 2018**



# Signal Timing Development in Pennsylvania

“The way we’ve always done it”



# Is this better?

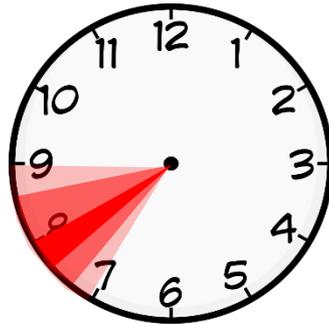


# Traditional: Model a lot... Measure a little

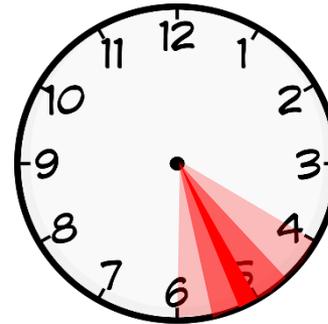


APRIL						
S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

One "typical" day



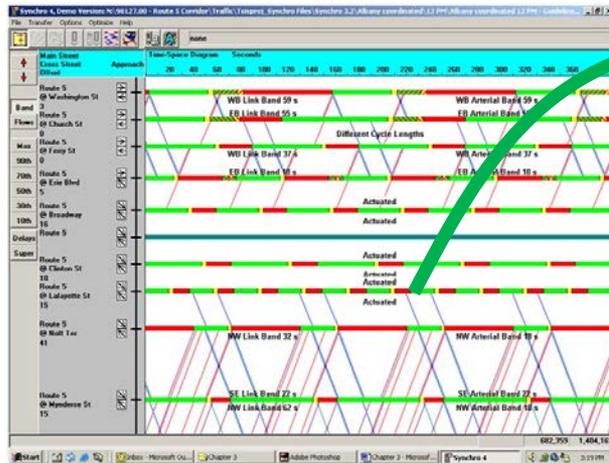
Count a few peak periods



Find peak hour

Apply peak hour factor  
Analyze peak 15 min.

2 peak hours on 1 day =  
0.005% of a year



Outputs:  
Cycle Length  
Splits  
Offsets



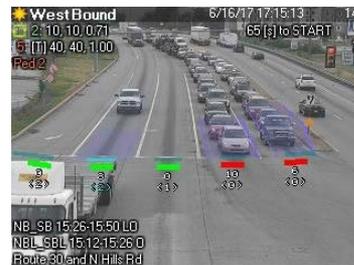
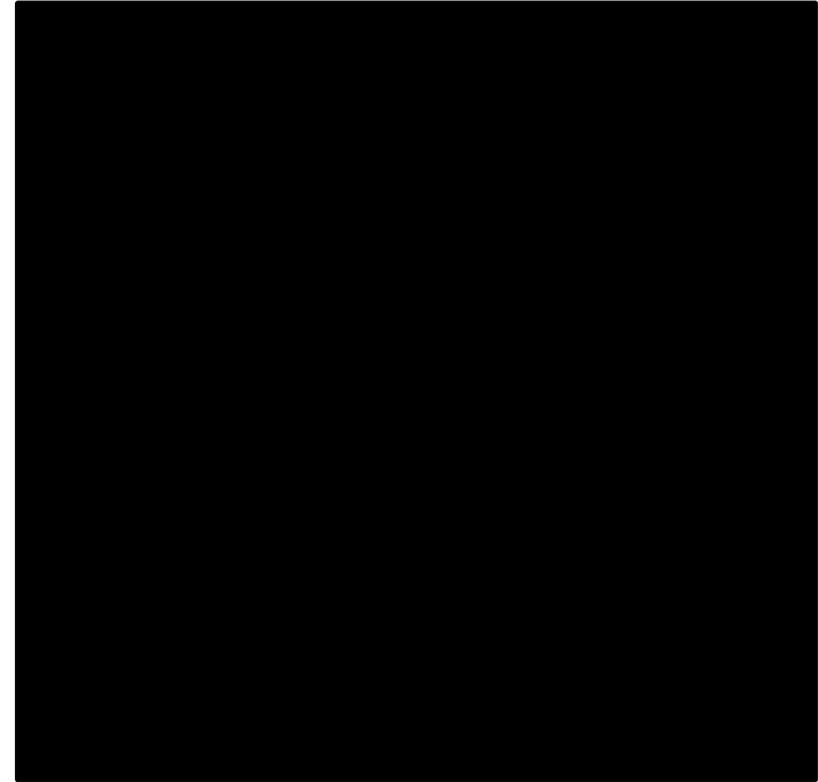
All of our metrics are based on **outputs** not Objectives

# Is this better?



**Data  
Collection**

**Modeling**



# A Better Way

## Traditional Process (Reactive)

Adapted from UDOT



Complaints  
Developer Impact

Outputs:  
Cycle Length  
Splits  
Offsets



## Modified Process with Performance Data (Proactive)

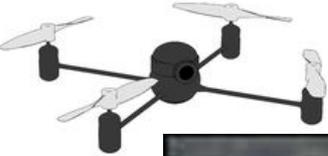


How do measures  
compare to  
agency goals?

Output:  
Offsets

# Using Data to Measure Arterial Performance

## Corridor Level



- Probe speed data
- RITIS/PDA Suite

## Intersection Level



- High resolution data
- UDOT ATSPM software

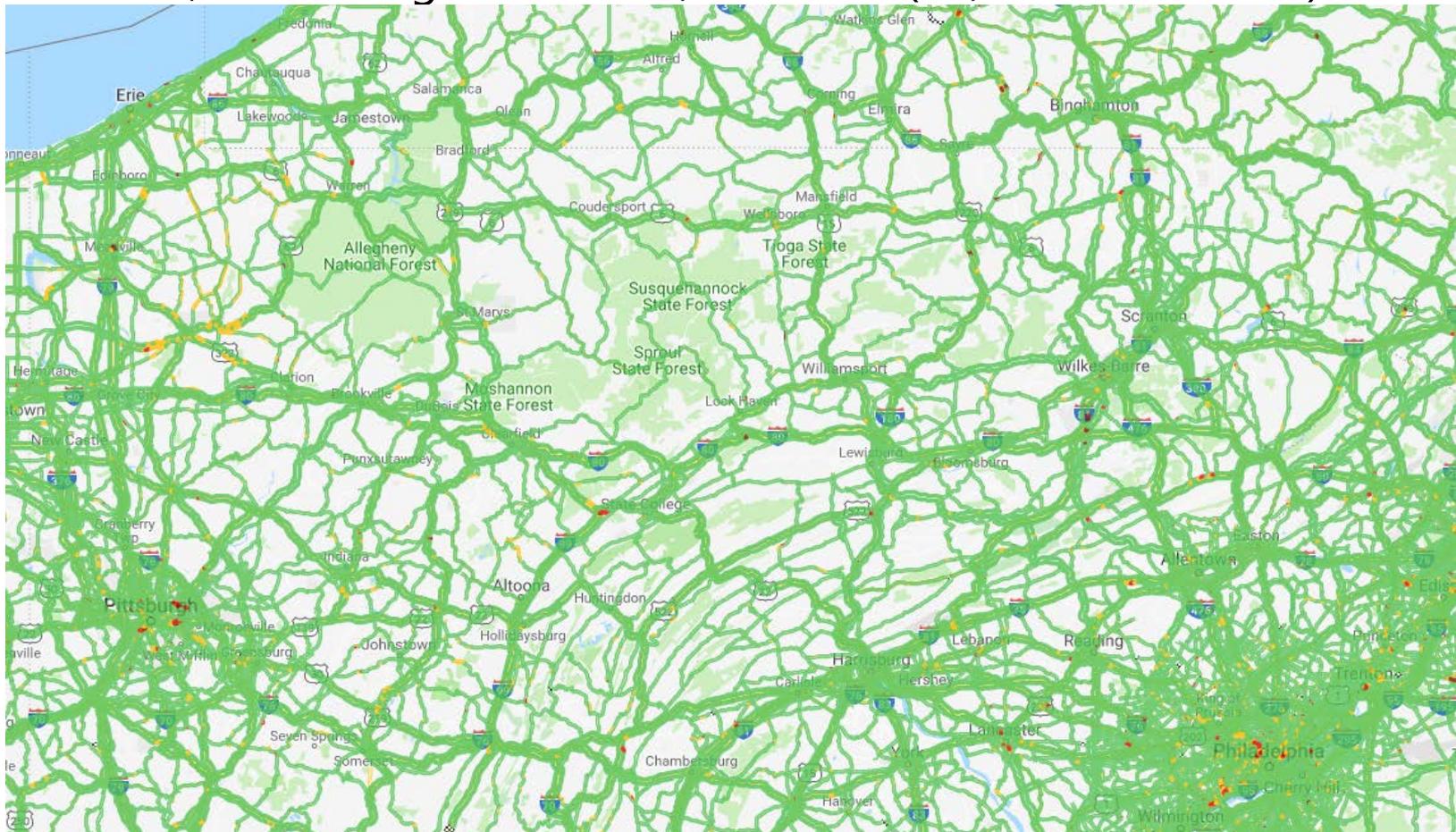
# Corridor Level Metrics

Phase 1: Proof of Concept

Phase 2: Enabling Access, Scalability, and Usability

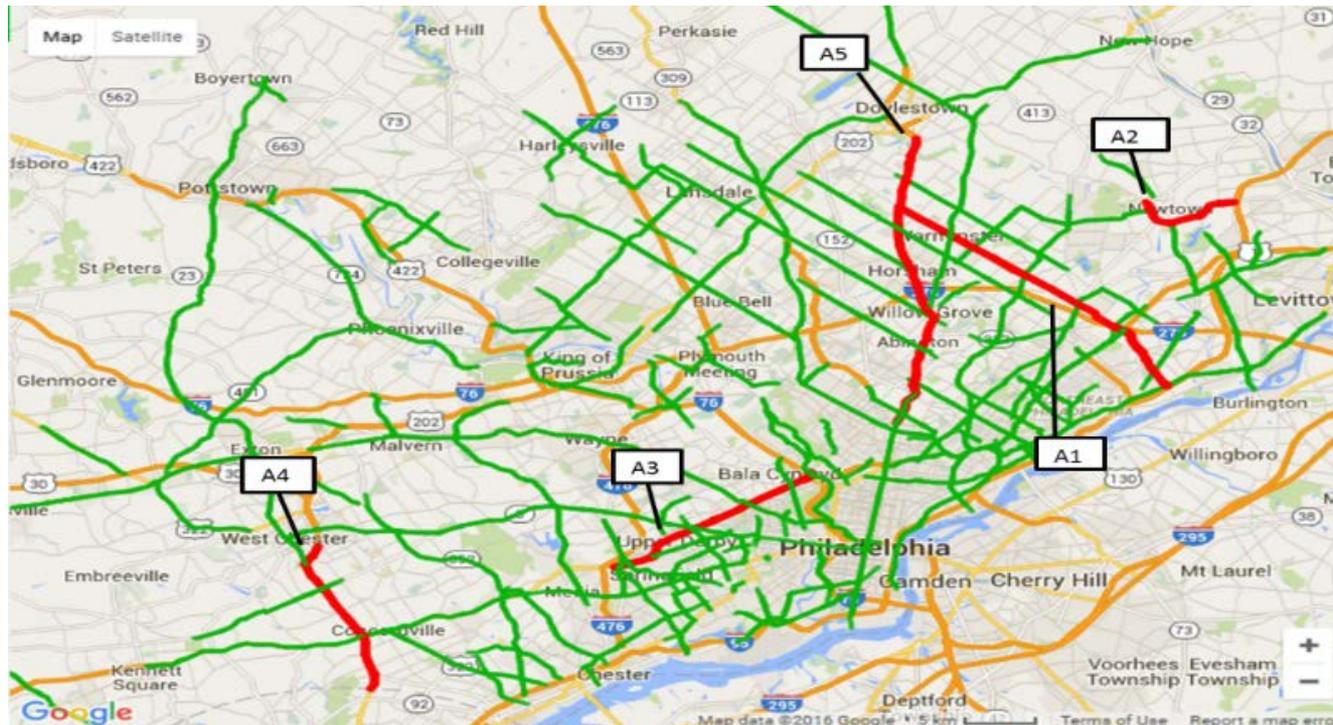
# Probe Data

- Pennsylvania INRIX coverage
  - 25,000 TMC segments = 16,600 miles
  - 112,000 XD segments = 23,200 miles (20,200 on arterials)



# Research / Proof of Concept

- TRB Annual Meeting 2017 Paper # 17-00314
  - <http://docs.trb.org/prp/17-00314.pdf>
- Proof of Concept
  - 138 “Super-Critical” corridors in Philadelphia area
  - Covered 2,184 signals on 766 miles of arterials

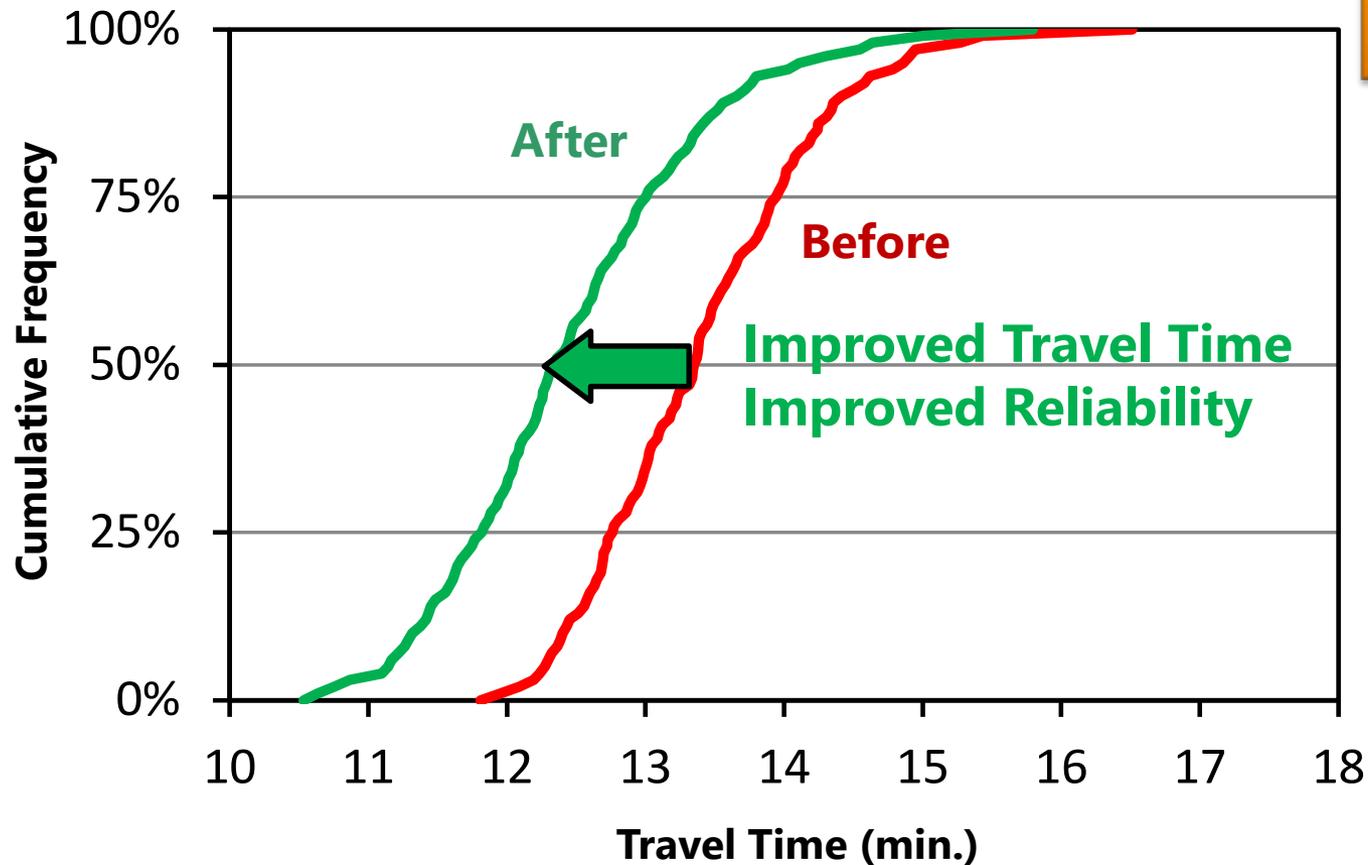


# Travel Time Comparison

- Travel Time
- Reliability

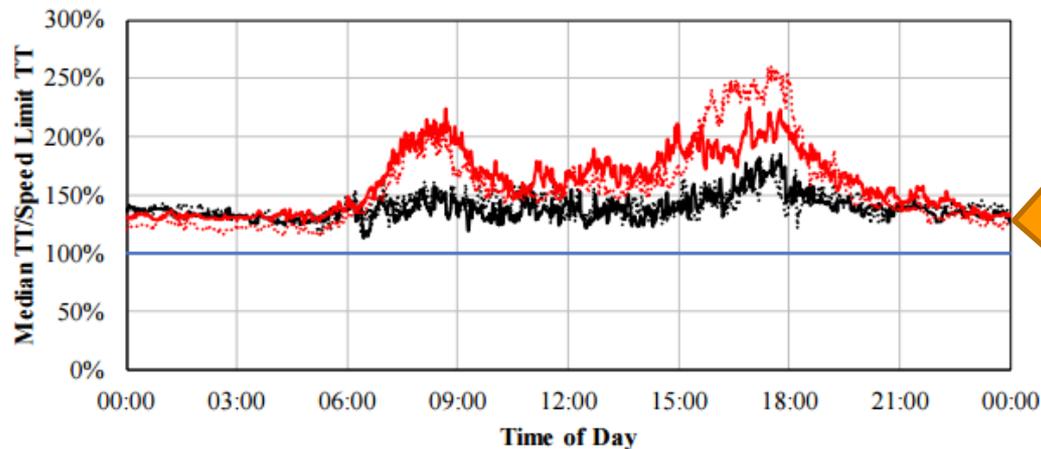
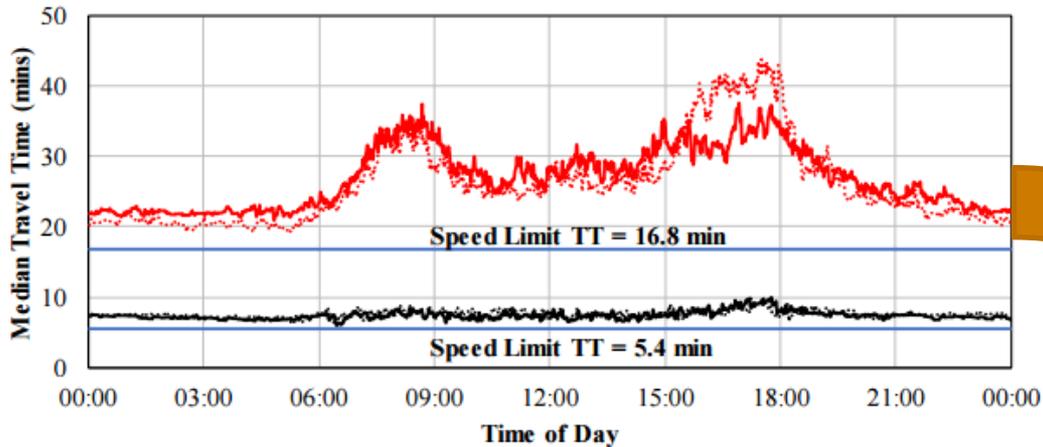
MARCH 2012							APRIL 2012						
S	M	T	W	T	F	S	S	M	T	W	T	F	S
				1	2	3	1	2	3	4	5	6	7
4	5	6	7	8	9	10	8	9	10	11	12	13	14
11	12	13	14	15	16	17	15	16	17	18	19	20	21
18	19	20	21	22	23	24	22	23	24	25	26	27	28
25	26	27	28	29	30	31	29	30					

**Retiming  
Week**



# Travel Time Normalization

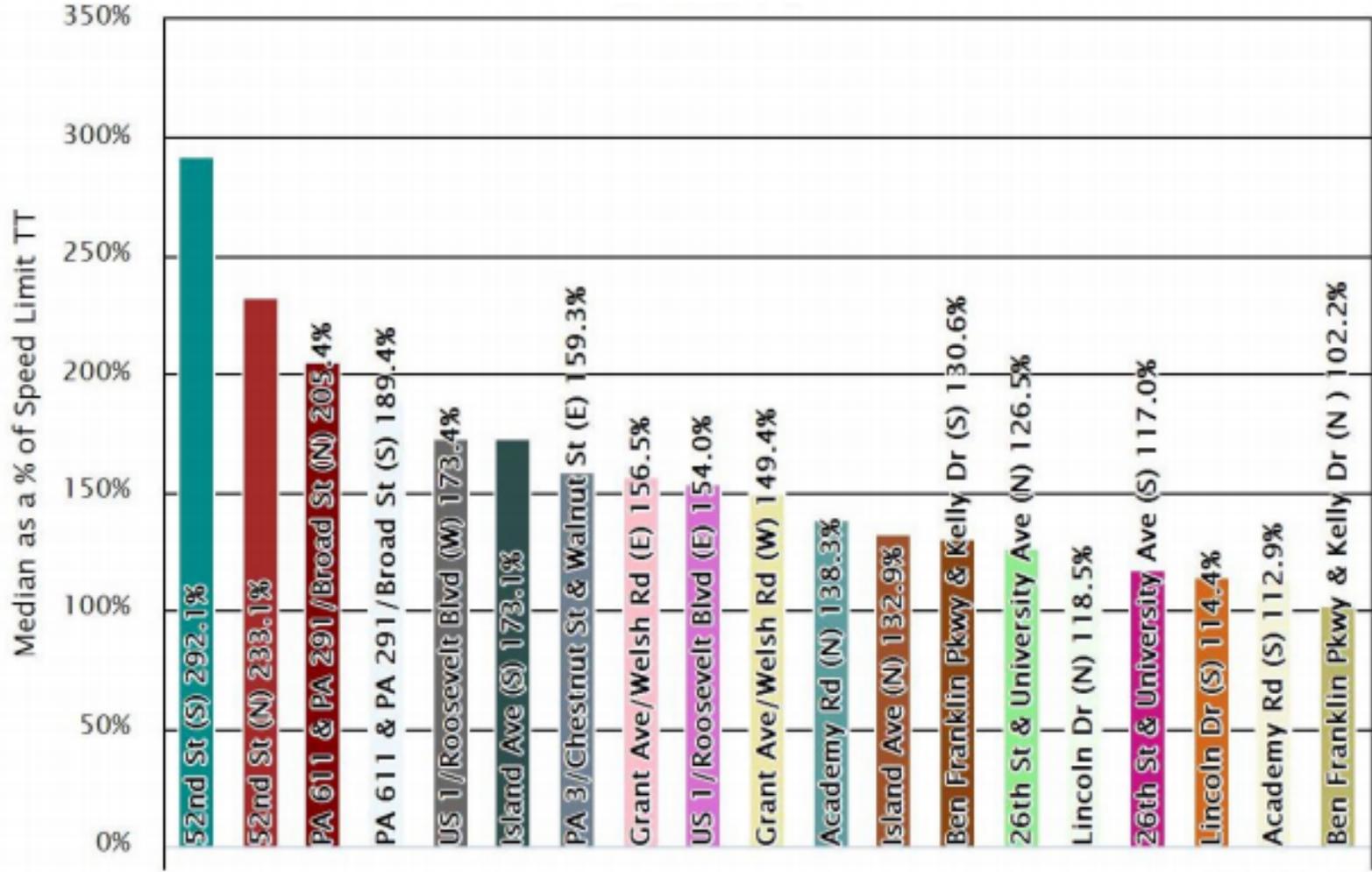
- Normalize corridors of difference length and speed limits
- Identify corridors with below average performance



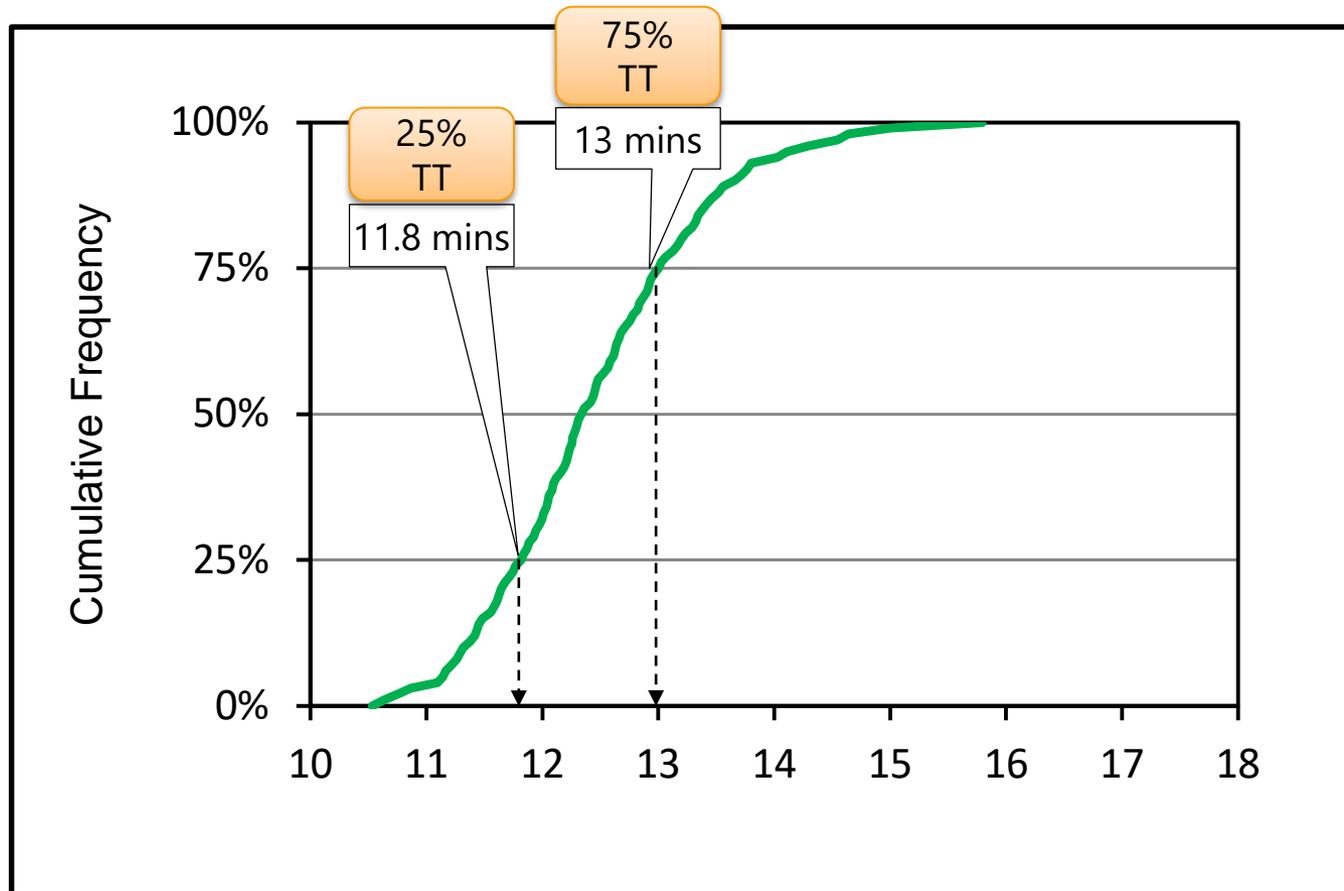
Normalize  
travel times

Median TT  
Speed Limit TT

# Travel Time Normalization



# Interquartile-Range (IQR) Normalization



$$\text{Normalized IQR} = \frac{(75\text{th percentile TT} - 25\text{th percentile TT})}{\text{Speed limit TT}}$$



# PDA Suite: Corridor and Time Selection

Probe Data Analytics Suite  Welcome, Jenny | [My History](#) | [Help](#) | [Tutorials](#) | [Logout](#)

## Travel Time Comparison

Travel time comparison allows you to compare a road's travel time against two different time ranges to not an upgrade or downgrade in performance.

### 1. Select a road

Roads | List of XD codes | Saved XD sets [Advanced](#)

XDs from...  Search in Pennsylvania...

Your selected road  Remove all 

▼ US 30   

Directions:  
 Eastbound  Westbound  
 Entire road  Partial road  
85 miles of roadway selected (52 XD segments)   
[Report a problem with this road](#) 

 Save as XD set

### 2. Create one or more time periods

Day(s) | Month(s) | Year(s)

- through -

Limit to specific days of the week

Sun  Mon  Tue  Wed  Thu  Fri  Sat

 Add time period

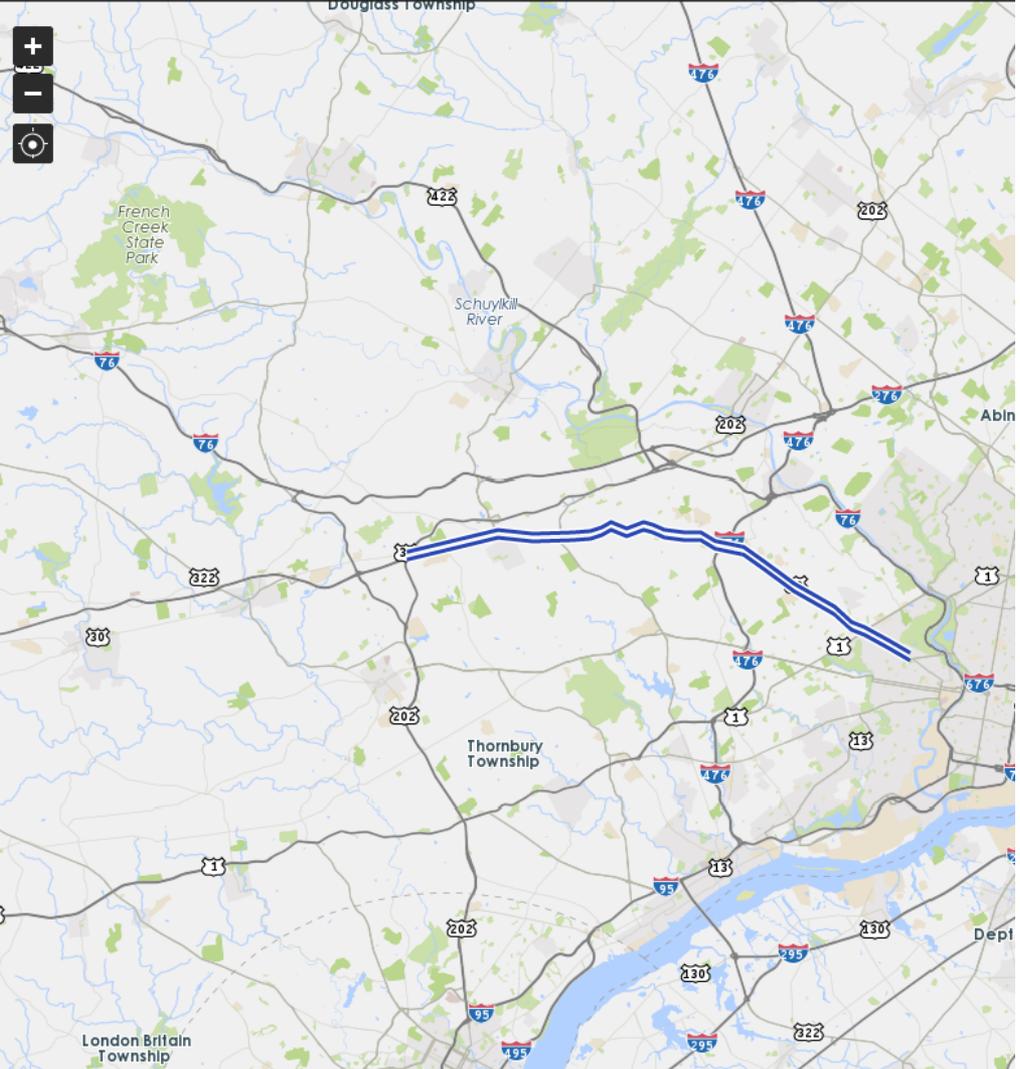
Your selected time periods Remove all 

08/21/2017 - though - 08/25/2017 

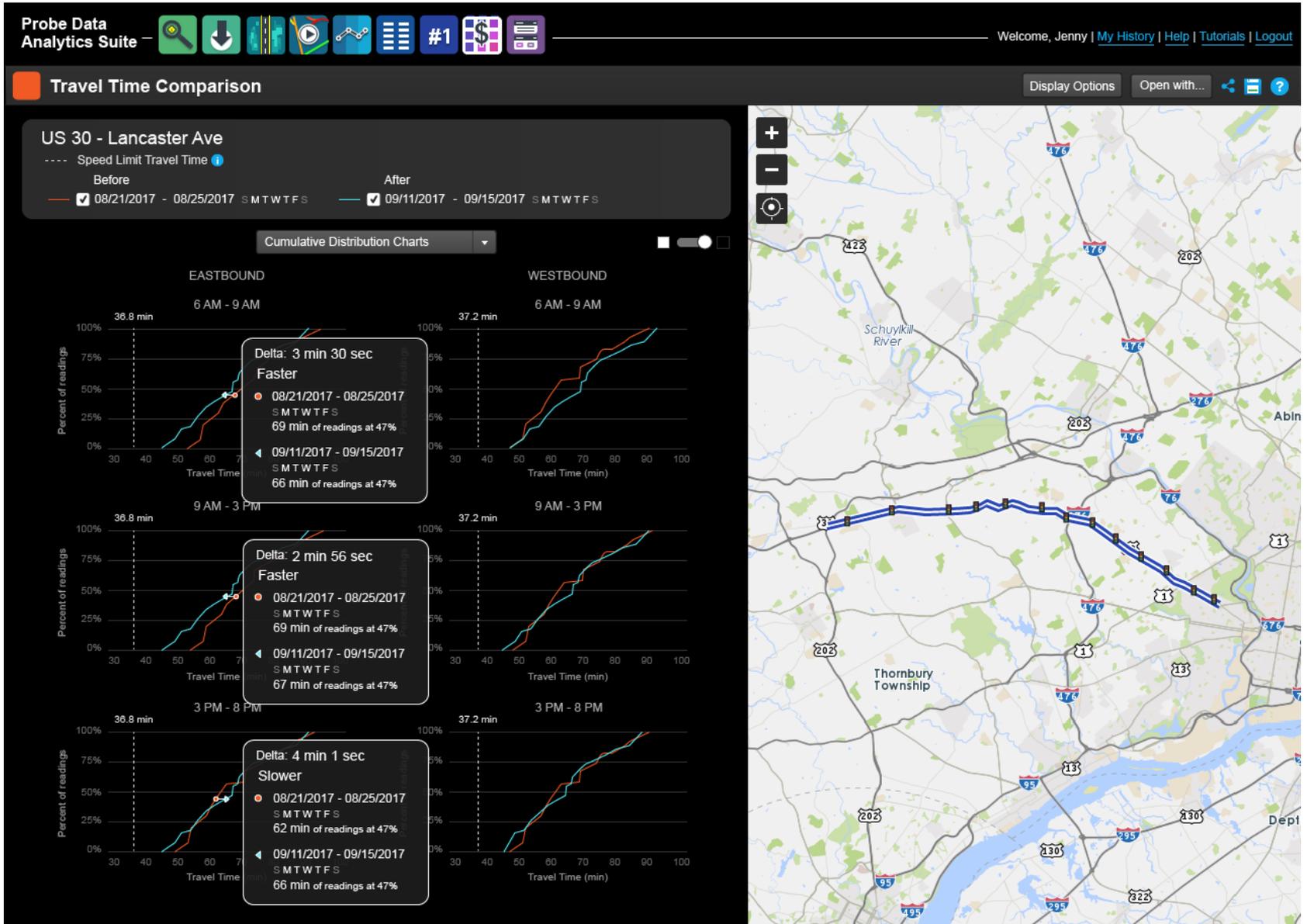
### 3. Choose one to three time ranges to analyze within each time period

Use default Peak Hours   
 Use custom hours

12:00 AM | 12:00 PM | 12:00 AM



# PDA Suite: Travel Time Comparison



# PDA Suite: Cumulative Distribution Chart



## Travel Time Comparison

### US 30 - Lancaster Ave

---- Speed Limit Travel Time

Before

After

08/21/2017 - 08/25/2017 S M T W T F S

09/11/2017 - 09/15/2017 S M T W T F S

Cumulative Distribution Charts

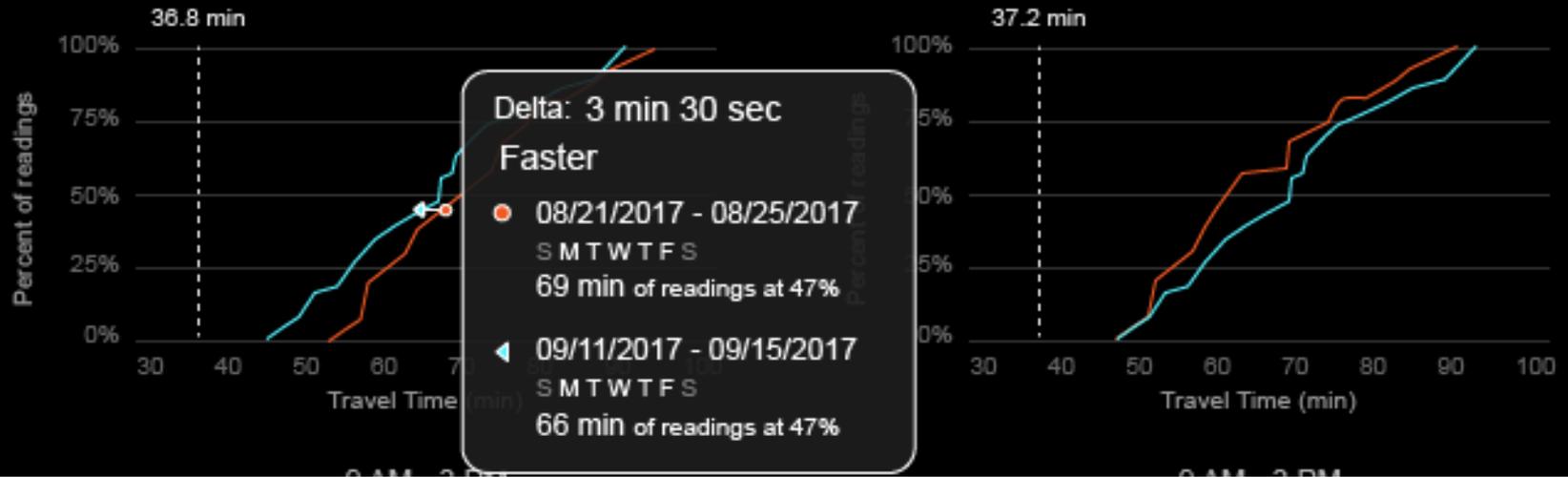


EASTBOUND

WESTBOUND

6 AM - 9 AM

6 AM - 9 AM



# PDA Suite: Change Between Dates

## Travel Time Comparison

### US 30 - Lancaster Ave

Before

08/21/2017 - 08/25/2017 SMTWTF S

After

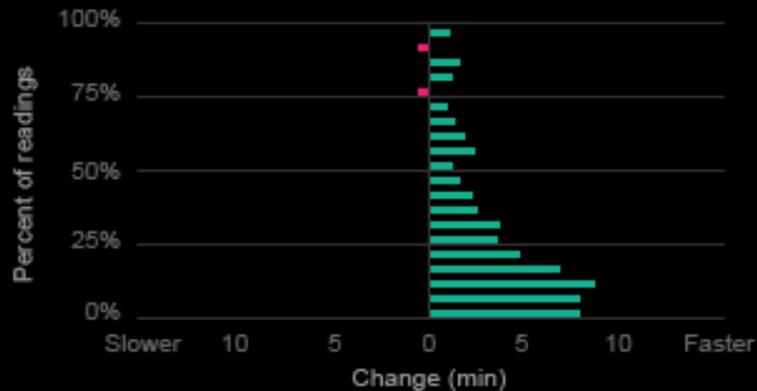
09/11/2017 - 09/15/2017 SMTWTF S

Change Between Dates



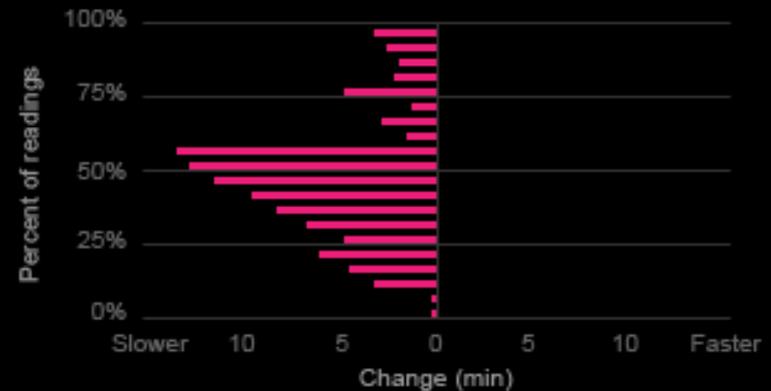
EASTBOUND

6 AM - 9 AM



WESTBOUND

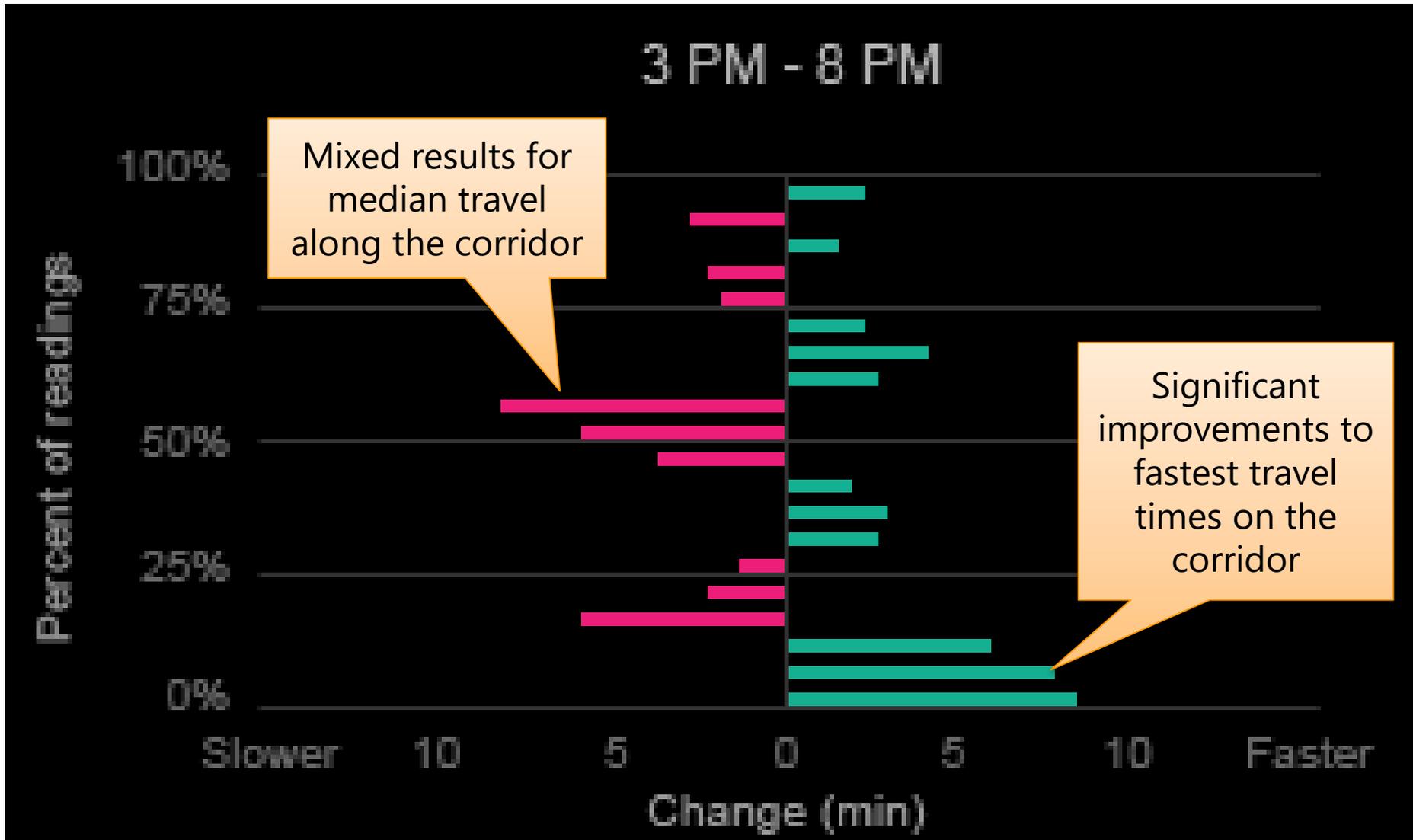
6 AM - 9 AM



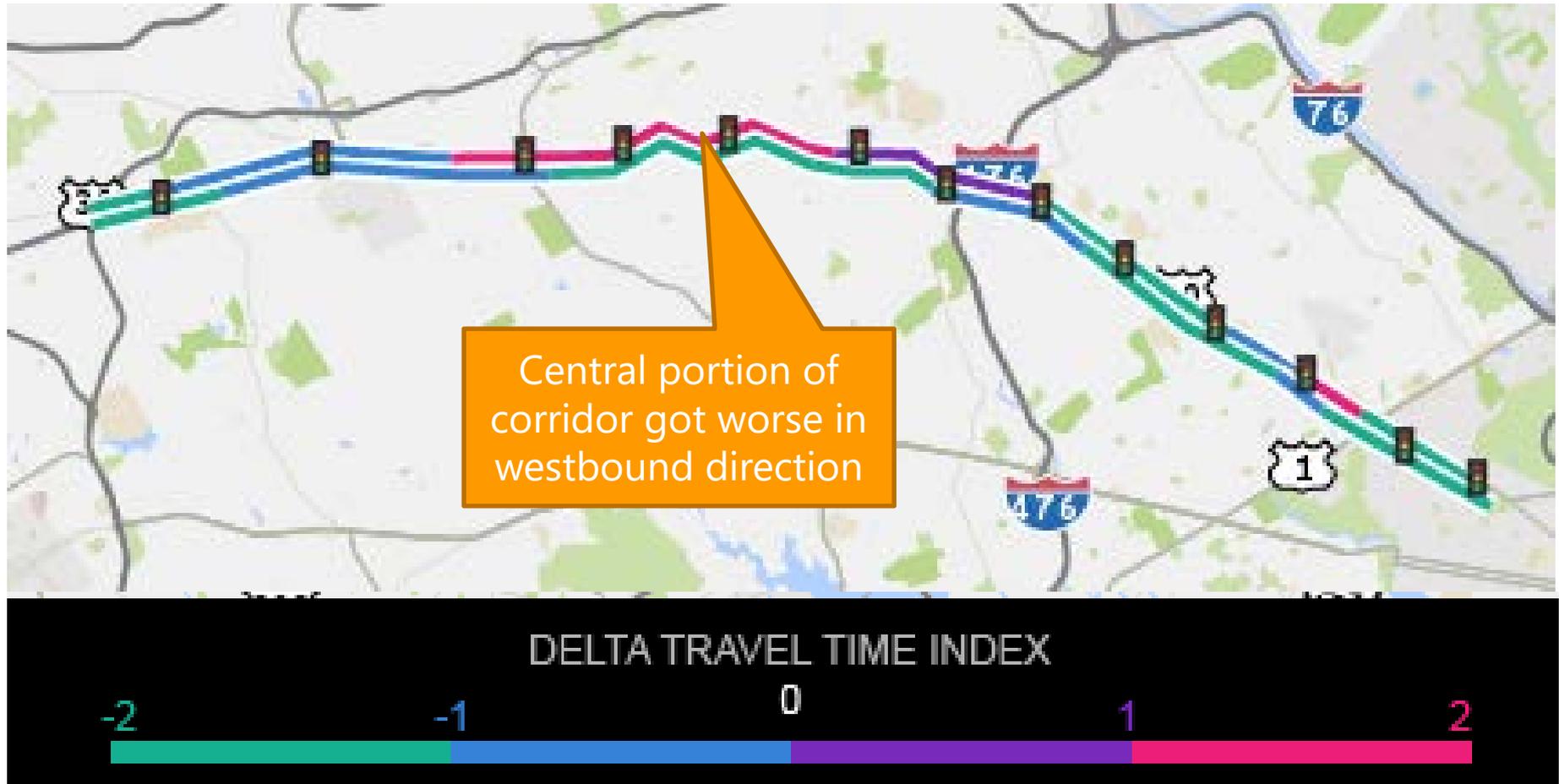
DELTA TRAVEL TIME INDEX



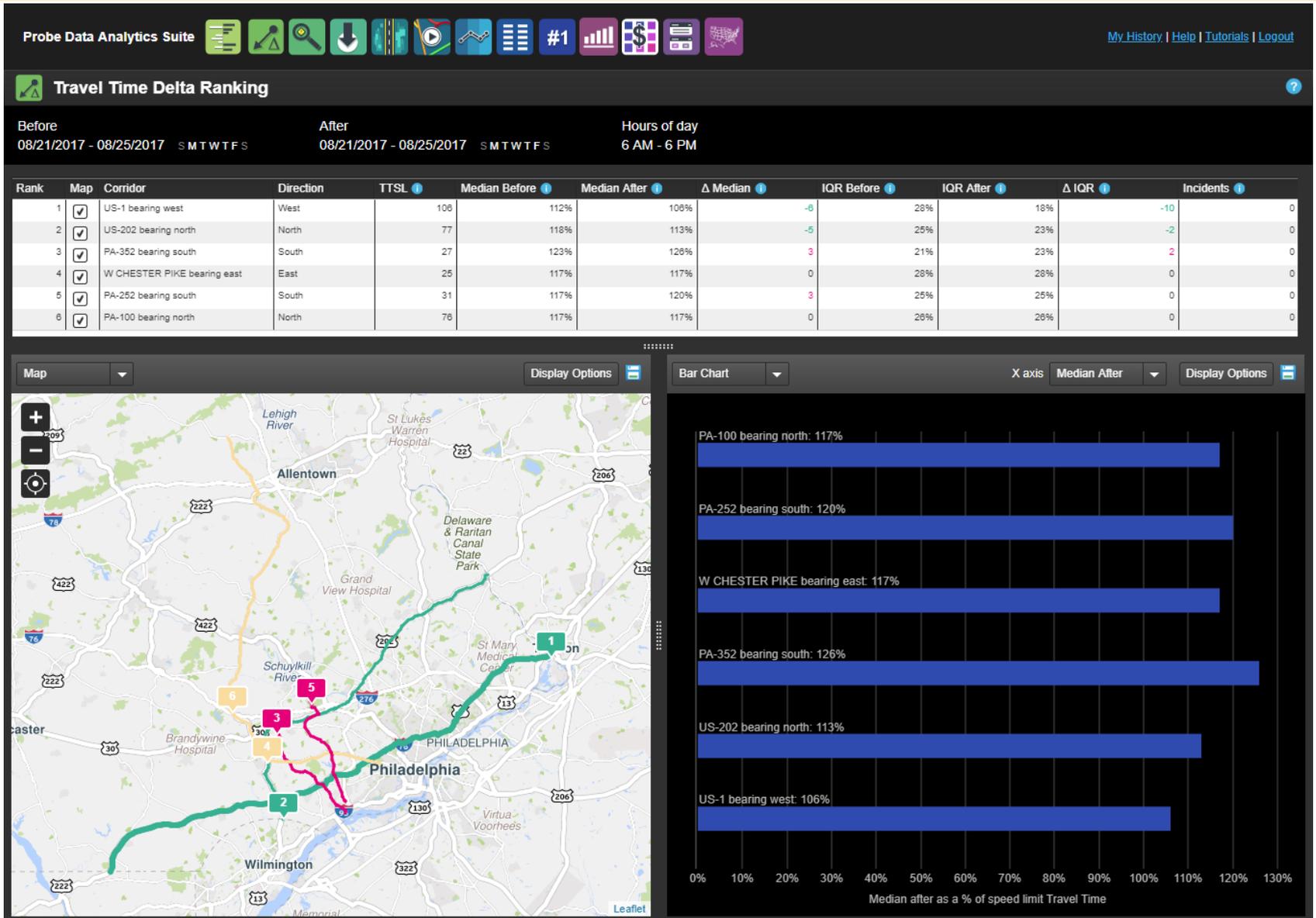
# PDA Suite: Change Between Dates



# PDA Suite: Change Between Dates



# PDA Suite: Travel Time Delta Ranking



# PDA Suite: Travel Time Delta Ranking (Slope Chart)



# Intersection-Level Metrics

# High Res Data: A Fitness Tracker for Traffic Signals

## High Resolution Data Collection

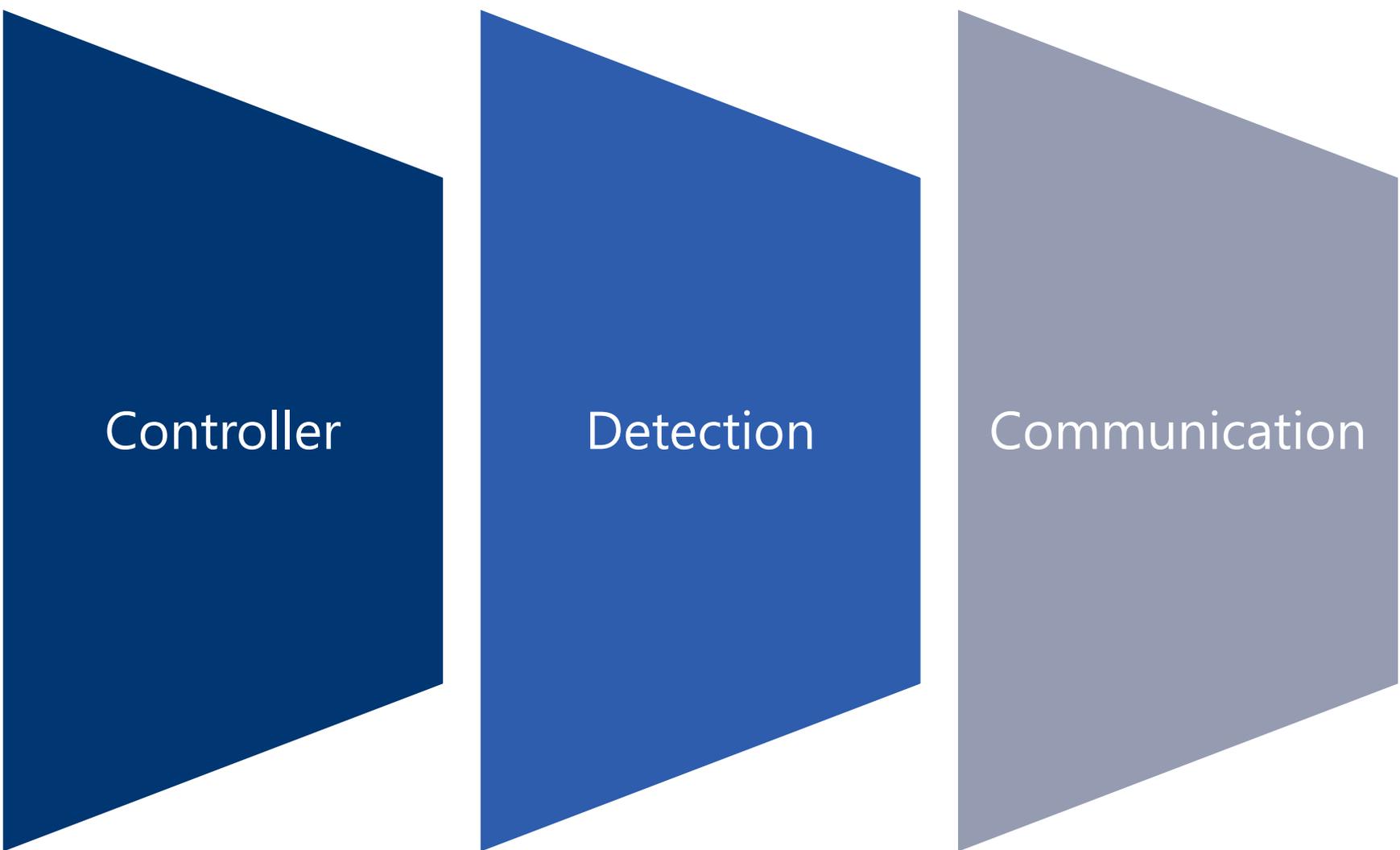


## Data Analysis & Performance Reporting



Source: FHWA

# ATSPM Implementation



Controller

Detection

Communication

# Implementing ATSPM: Controllers

- Buy a new controller for about the same price as doing one round of count, analyze & retime
- Vendor neutral
  - Bulletin 15 #'s in bold below
  - Links to manufacturer product sheets below



Econolite Cobalt: Any version **ECO-127P, 128P & 129P**  
Econolite ASC3 NEMA: v2.50+ & OS 1.14.03+ **ECO-116P**  
Econolite 2070 w/ 1C CPU: v 32.50+



Peek ATC: Greenwave 03.05.0528+ **PTS-042P**



McCain ATC Omni eX 1.6+ **MCC-018P**



Trafficware Model 980ATC: v 76.10+ **TFW-011P**  
Trafficware ATC Controller: v76.10+

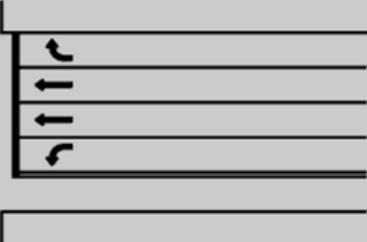
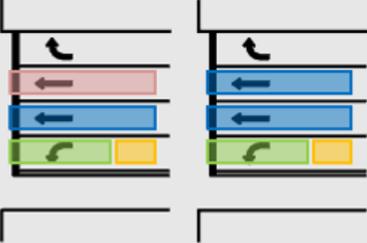


Intelight: Maxtime v1.7.0+ **INT-009P, 010P & 011P**



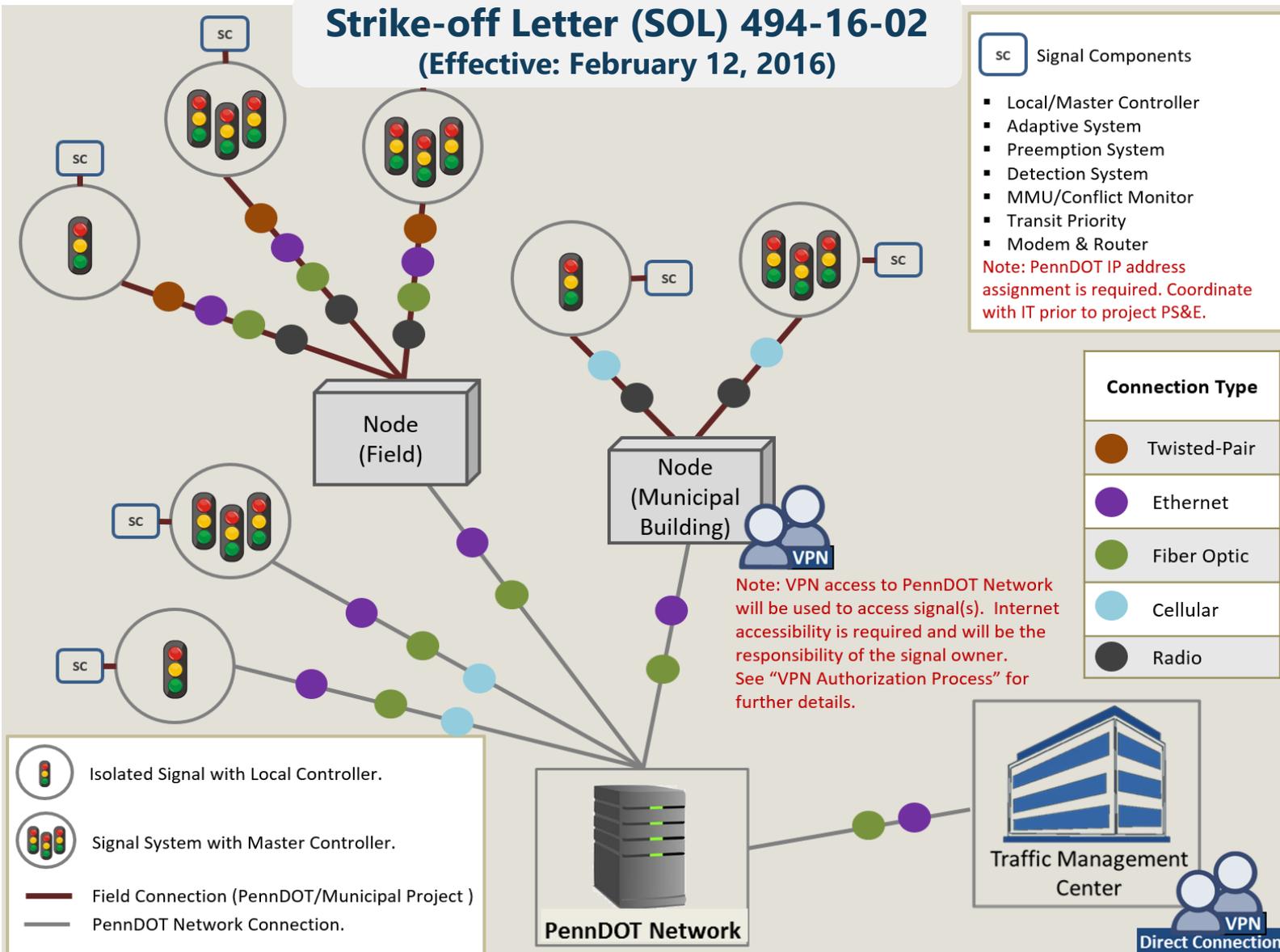
Siemens M50 *Linux*  
Siemens M60 ATC **SMS-231P**  
ECOM v 3.52+  
NTCIP v 4.53+

# Implementing ATSPM: Detection

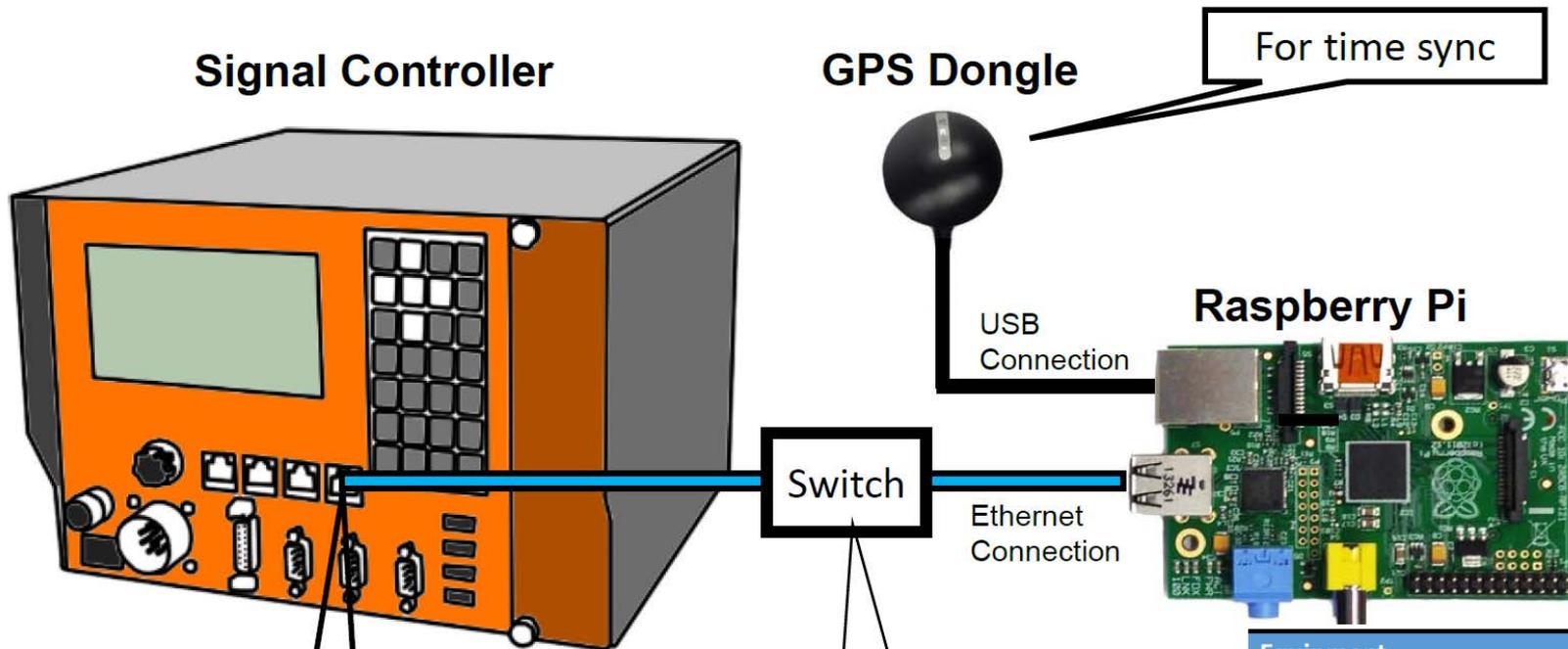
Detection		Metric
None		Phase Termination Chart Split Monitor Preemption Details Pedestrian Delay
Lane-by-lane Presence Lane Group Presence		Purdue Split Failure
Lane-by-lane Stop Bar Count		Turning Movement Counts
Advanced Count		Purdue Coordination Diagram Approach Volume Approach Speed (requires detection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

# Implementing ATSPM: Communication

## Strike-off Letter (SOL) 494-16-02 (Effective: February 12, 2016)



# Implementing ATSPM: No Communication



Optional

Software	Price
SD Formatter	Free
NOOBS v1.5 (OS package)	Free
cgps	Free
signalrpi (Purdue)	Free

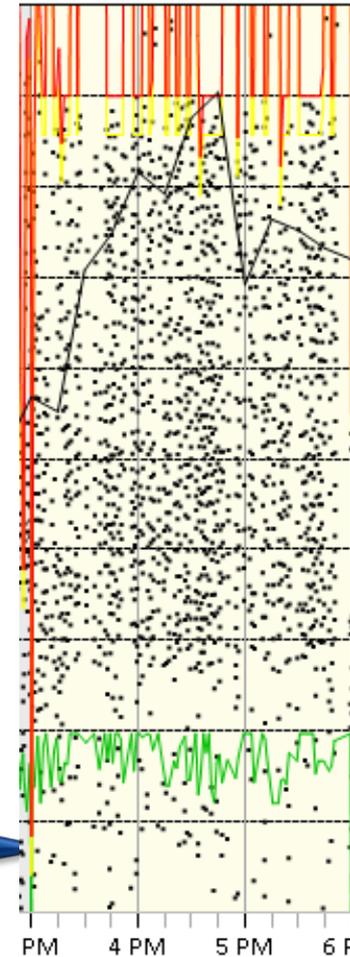
Equipment	Price
Raspberry Pi 2, Model B	\$35
Raspberry Pi Case	\$10
Power supply (5V, 1A)	\$6
USB to Micro USB (Power Cable)	\$4
MicroSD card (16GB)	\$10
Ethernet Cable	\$2
HDMI Video Cable	\$8
GPS Module (GlobalSat BU-353-S4)	\$30
Ethernet Switch – <i>optional</i>	\$25
<b>Total</b>	<b>\$130</b>

# ATSPM: Improve progression on critical corridors

- Purdue Coordination Diagram

%AoG >  
% GT

Plan 2  
96% AoG  
86% GT  
1.12 PR  
AT 3.9



Few  
arrivals  
on red

# ATSPM: Split Failures

- **Green Occupancy Ratio (GOR)**
  - % of time detection zone occupied while signal is **green** for the lane(s) served by the phase
- **Red Occupancy Ratio (ROR)**
  - % of time detection zone occupied during **first 5 seconds of red** for the lane(s) served by the phase

- **Split Failure**

80%+ **GOR**

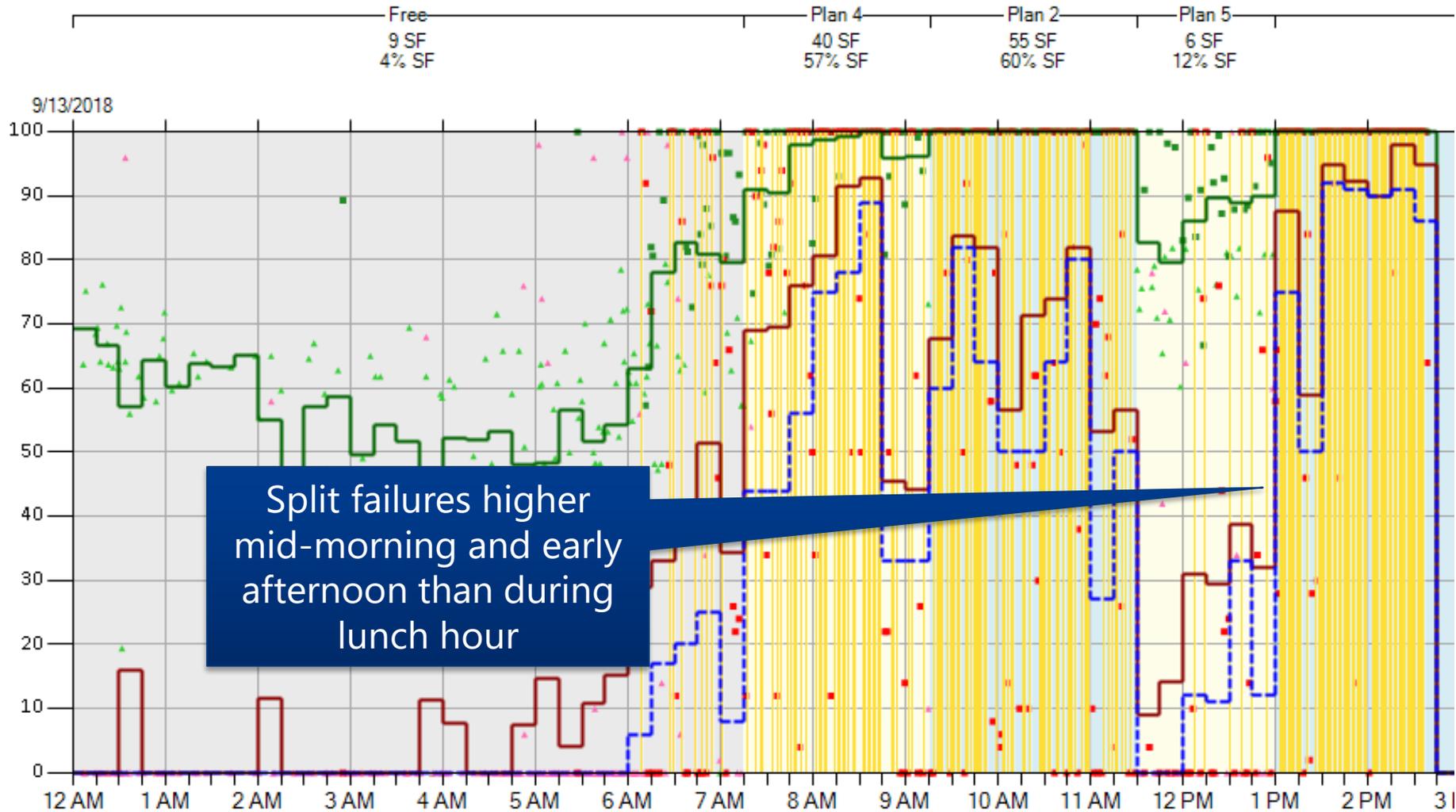
AND

80%+ **ROR**

## Termination Type

- GOR - GapOut
- GOR - ForceOff
- ROR - GapOut
- ROR - ForceOff
- SplitFail
- Avg. GOR
- Avg. ROR
- Percent Fails

# ATSPM: Minimize delay for intersecting users

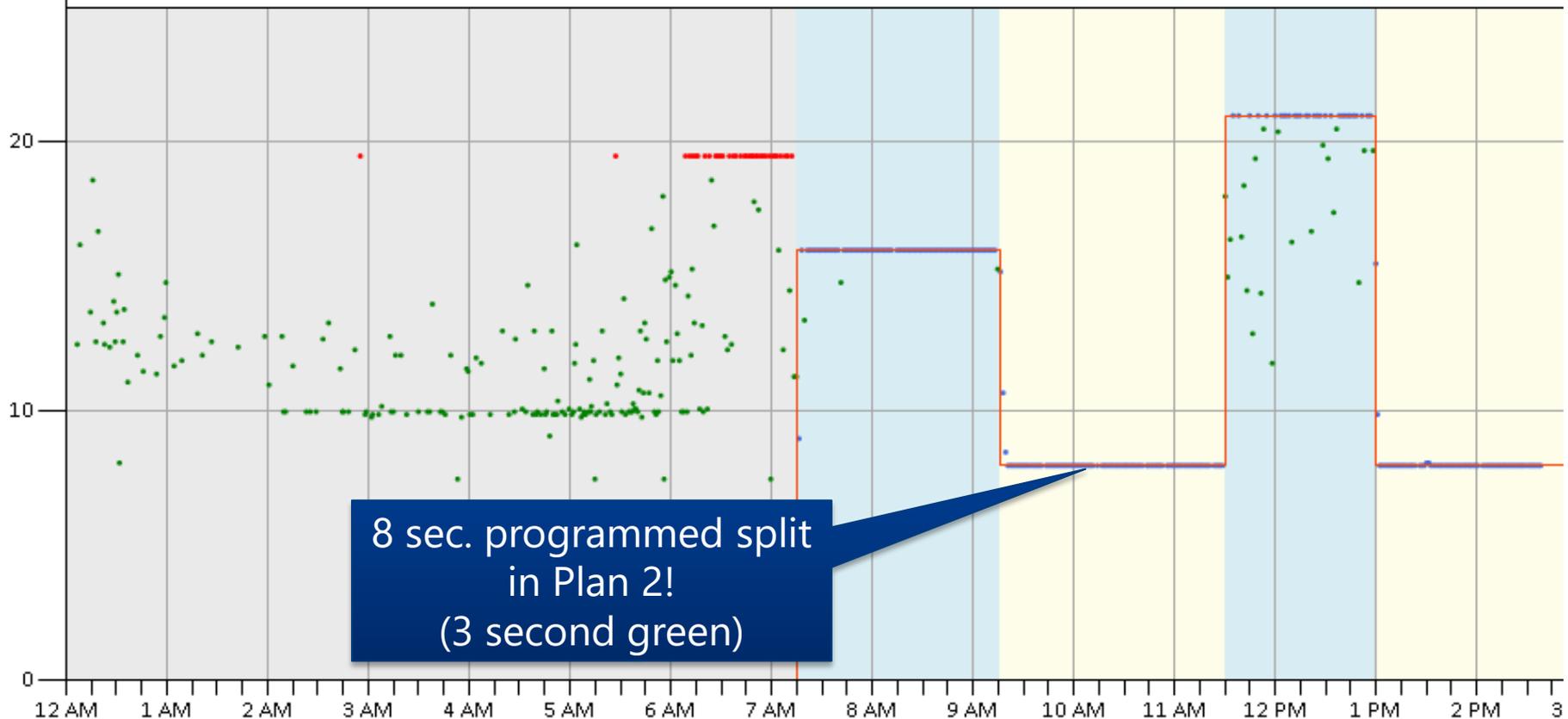


# Minimize delay for intersecting users



Free	Plan 4	Plan 2	Plan 5
19.5s - 85%tile Split	16s Programmed S...	8s Programmed Split	21s Program...
12.9s Avg. Split	16.0s - 85%tile Split	8.0s - 85%tile Split	21.0s - 85%til...
10.0% MaxOuts	15.8s Avg. Split	8.0s Avg. Split	19.5s Avg. Sp...
51.7% GapOuts	94.4% ForceOffs	93.0% ForceOffs	55.6% Force...
38.3% Skips	4.2% GapOuts	0.0% GapOuts	37.0% GapOu...
	1.4% Skips	7.0% Skips	7.4% Skips

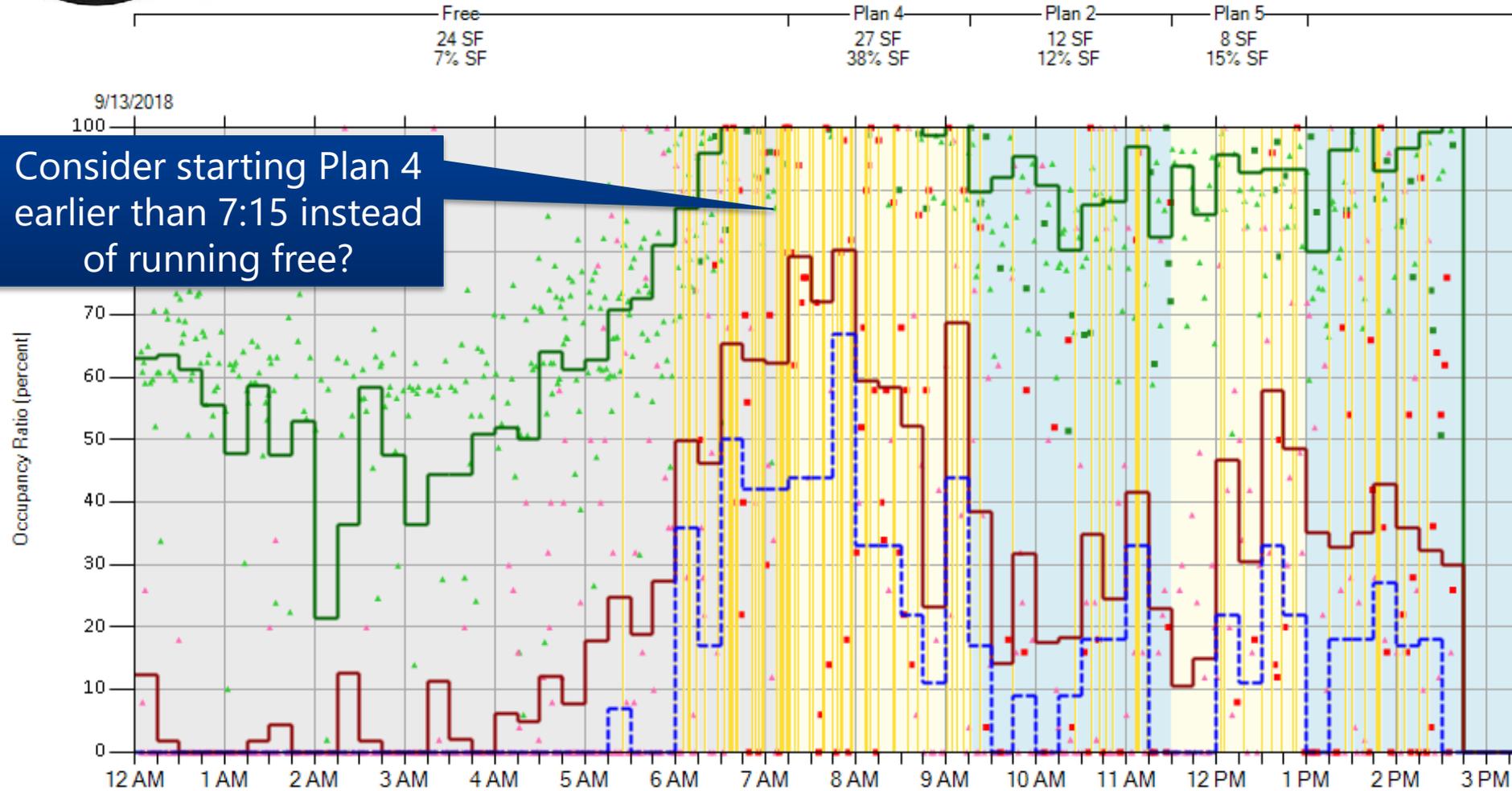
9/13/2018



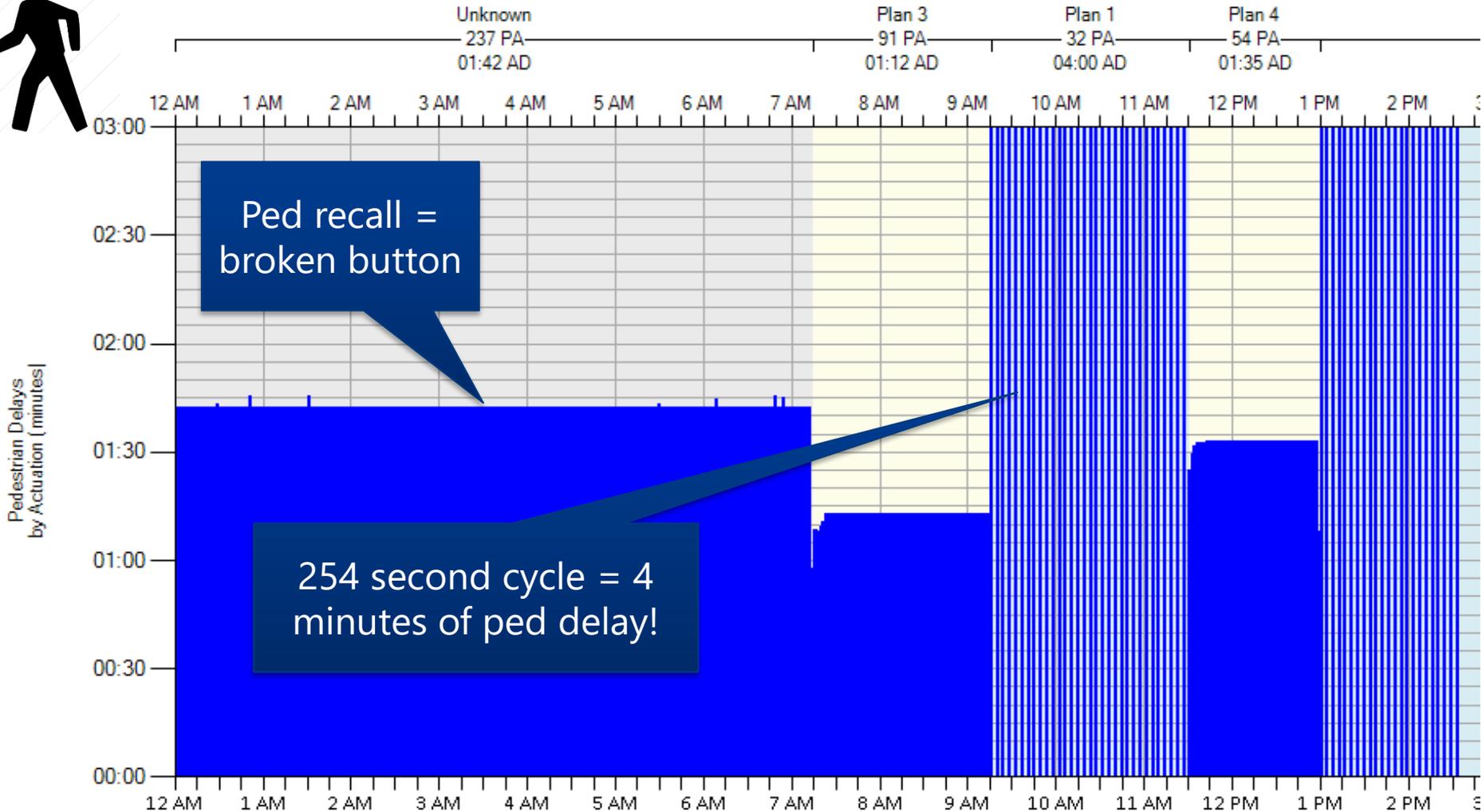
8 sec. programmed split  
in Plan 2!  
(3 second green)



# Minimize delay for intersecting users



# ATSPM: Minimize delay for intersecting users

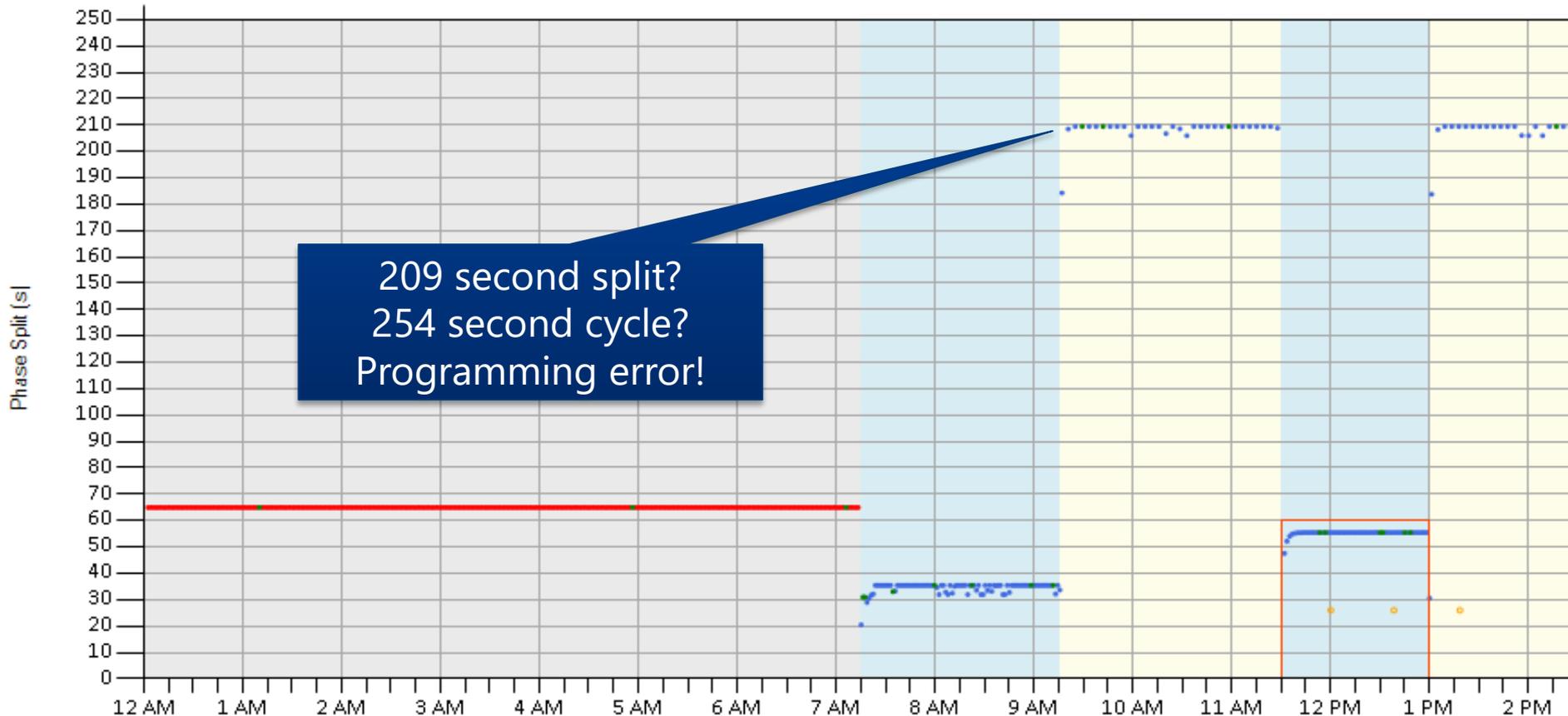


# ATSPM: Maintain equipment



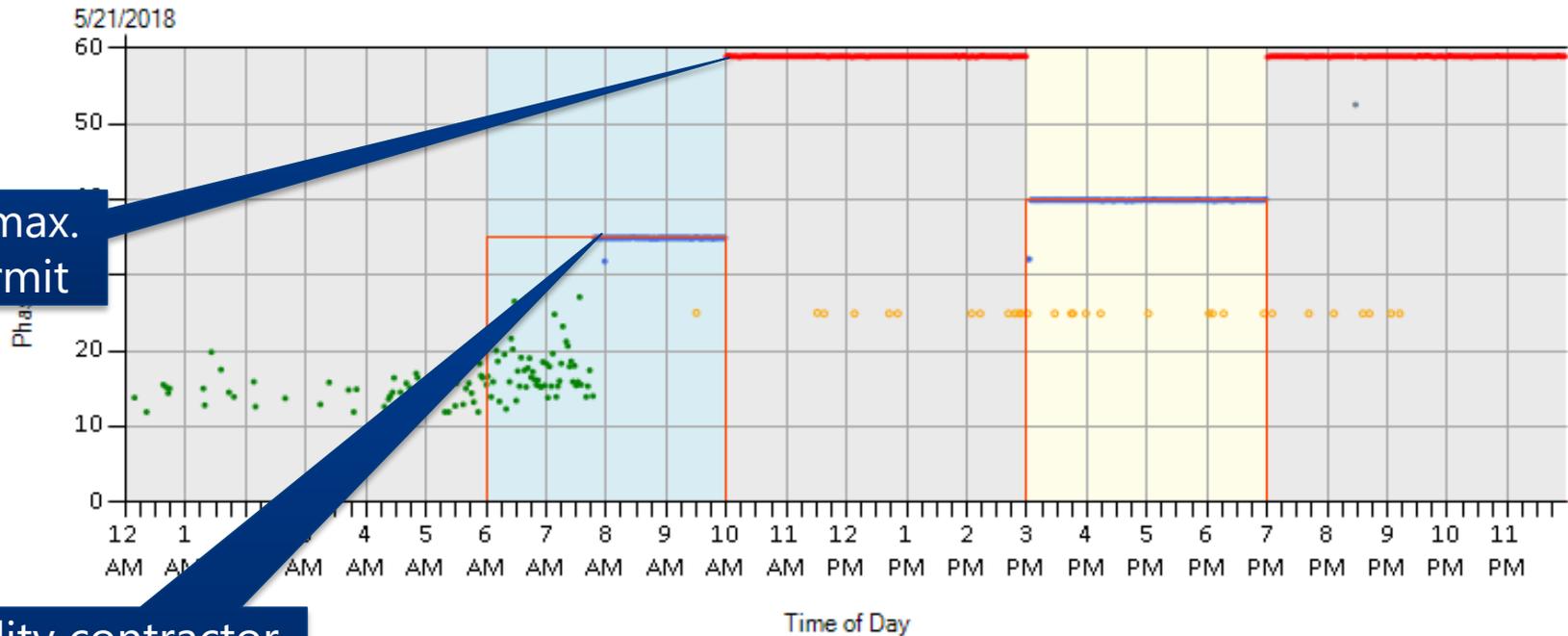
Free	Plan 3	Plan 1	Plan 4
65.0s - 85%tile Split	0s Programmed Split	0s Programmed Split	60s Program...
65.0s Avg. Split	35.5s - 85%tile Split	209.5s - 85%tile Split	55.5s - 85%til...
98.7% MaxOuts	34.5s Avg. Split	208.3s Avg. Split	55.2s Avg. Sp...
1.3% GapOuts	92.3% ForceOffs	87.5% ForceOffs	87.0% Force...
0.0% Skips	7.7% GapOuts	9.4% GapOuts	11.1% GapO...
	0.0% Skips	3.1% Skips	1.9% Skips

9/13/2018



# ATSPM: Maintain equipment

Free	Plan 1	Free	Plan 2	Free
	35s Programmed Sp...		40s Programmed Sp...	
16.8s - 85%tile Split	35.0s - 85%tile Split	59.0s - 85%tile Split	40.0s - 85%tile Split	59.0s - 85%tile Split
15.1s Avg. Split	27.8s Avg. Split	59.0s Avg. Split	39.9s Avg. Split	59.0s Avg. Split
0.0% MaxOuts	59.0% ForceOffs	100.0% MaxOuts	100.0% ForceOffs	97.8% MaxOuts
100.0% GapOuts	41.0% GapOuts	0.0% GapOuts	0.0% GapOuts	0.0% GapOuts
0.0% Skips	0.0% Skips	0.0% Skips	0.0% Skips	1.4% Skips



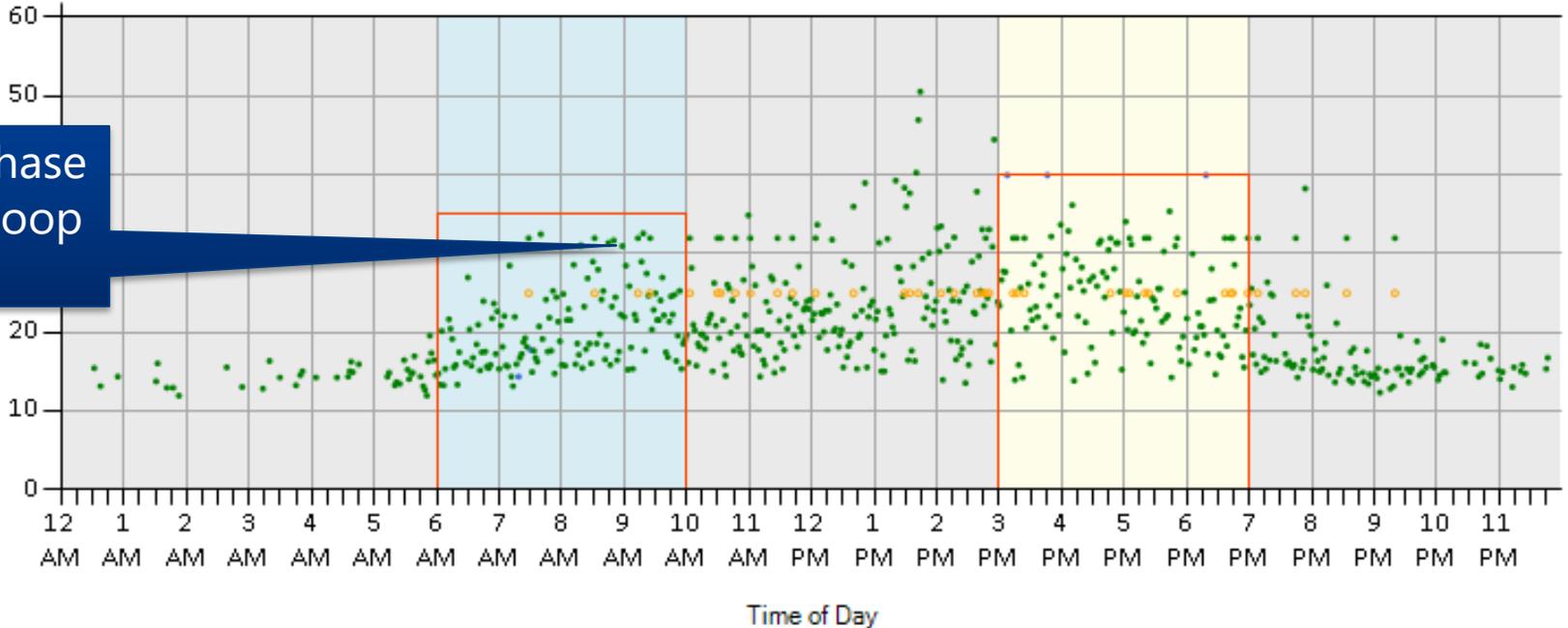
52 sec max.  
per permit

Utility contractor  
hit loop

# ATSPM: Maintain equipment

Free	Plan 1	Free	Plan 2	Free
16.3s - 85%tile Split	35s Programmed Sp... 25.8s - 85%tile Split	31.8s - 85%tile Split	40s Programmed Sp... 32.0s - 85%tile Split	20.9s - 85%tile Split
14.7s Avg. Split	20.7s Avg. Split	23.7s Avg. Split	24.6s Avg. Split	17.4s Avg. Split
0.0% MaxOuts	1.5% ForceOffs	0.0% MaxOuts	2.4% ForceOffs	0.0% MaxOuts
100.0% GapOuts	98.5% GapOuts	100.0% GapOuts	97.6% GapOuts	100.0% GapOuts
0.0% Skips	0.0% Skips	0.0% Skips	0.0% Skips	0.0% Skips

5/7/2018



### Termination Type

- Force Off
- Max Out
- Gap Out
- PedActivity
- Unknown
- Programmed Split

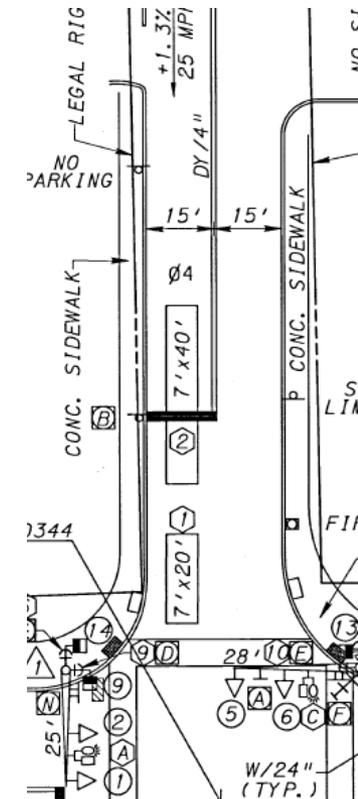
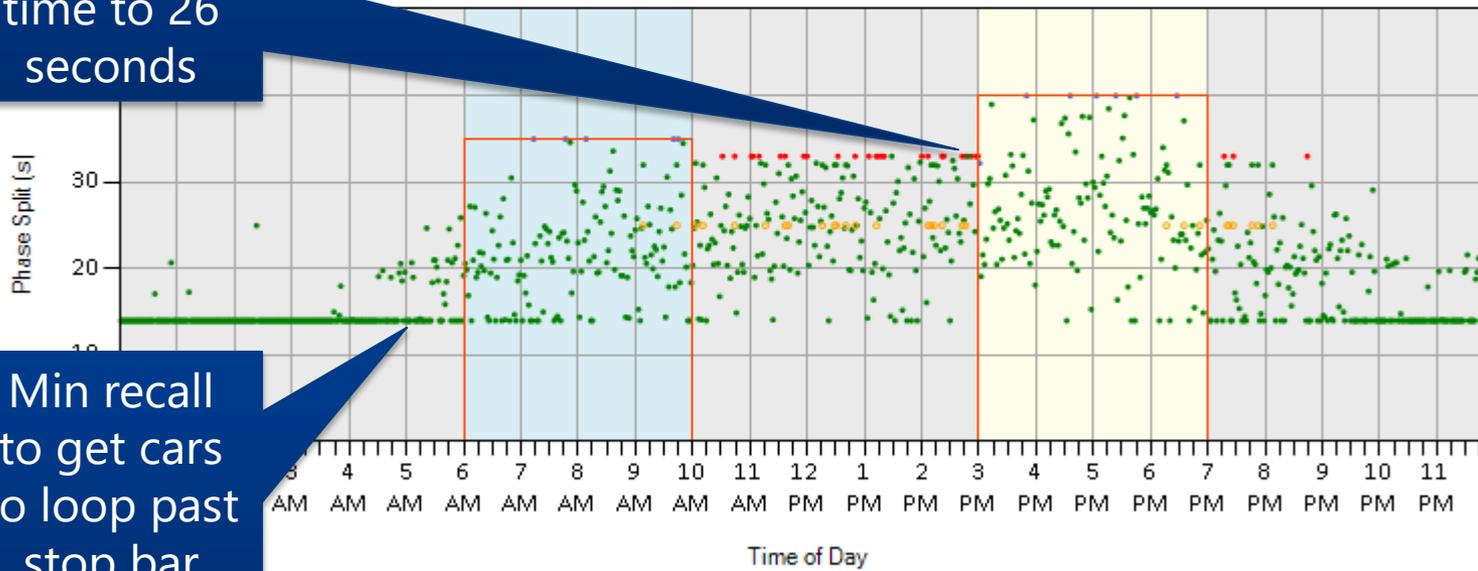
# ATSPM: Maintain equipment

Main Street (SR 0230) @ Barbara Street - Phase 8 - Monday 6/25/2018

Free	Plan 1	Free	Plan 2	Free
14.0s - 85%tile Split	35s Programmed Sp...	32.4s - 85%tile Split	40s Programmed Sp...	22.7s - 85%tile Split
17.8s Avg. Split	27.8s - 85%tile Split	25.6s Avg. Split	26.8s Avg. Split	17.8s Avg. Split
1.5% MaxOuts	3.5% ForceOffs	13.4% MaxOuts	5.3% ForceOffs	1.5% MaxOuts
95.8% GapOuts	95.8% GapOuts	86.0% GapOuts	94.7% GapOuts	98.5% GapOuts
0.0% Skips	0.7% Skips	0.5% Skips	0.0% Skips	0.0% Skips

Revised permit to reduce max time to 26 seconds

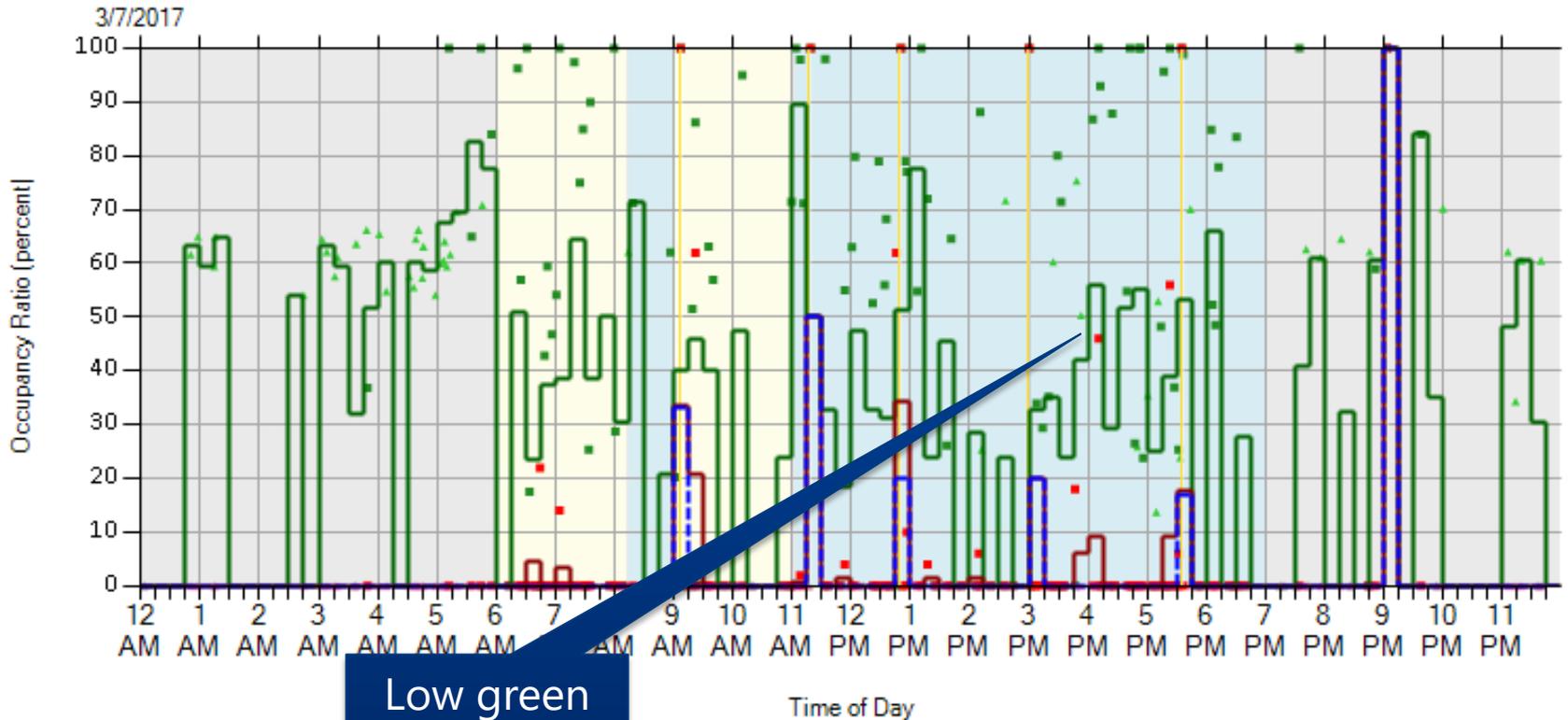
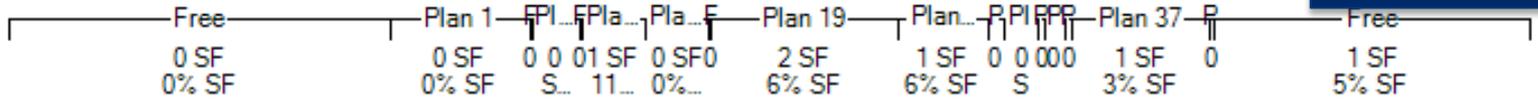
Min recall to get cars to loop past stop bar that was still working



# ATSPM: Example (Shippensburg, PA)

WB Left:  
Few split failures

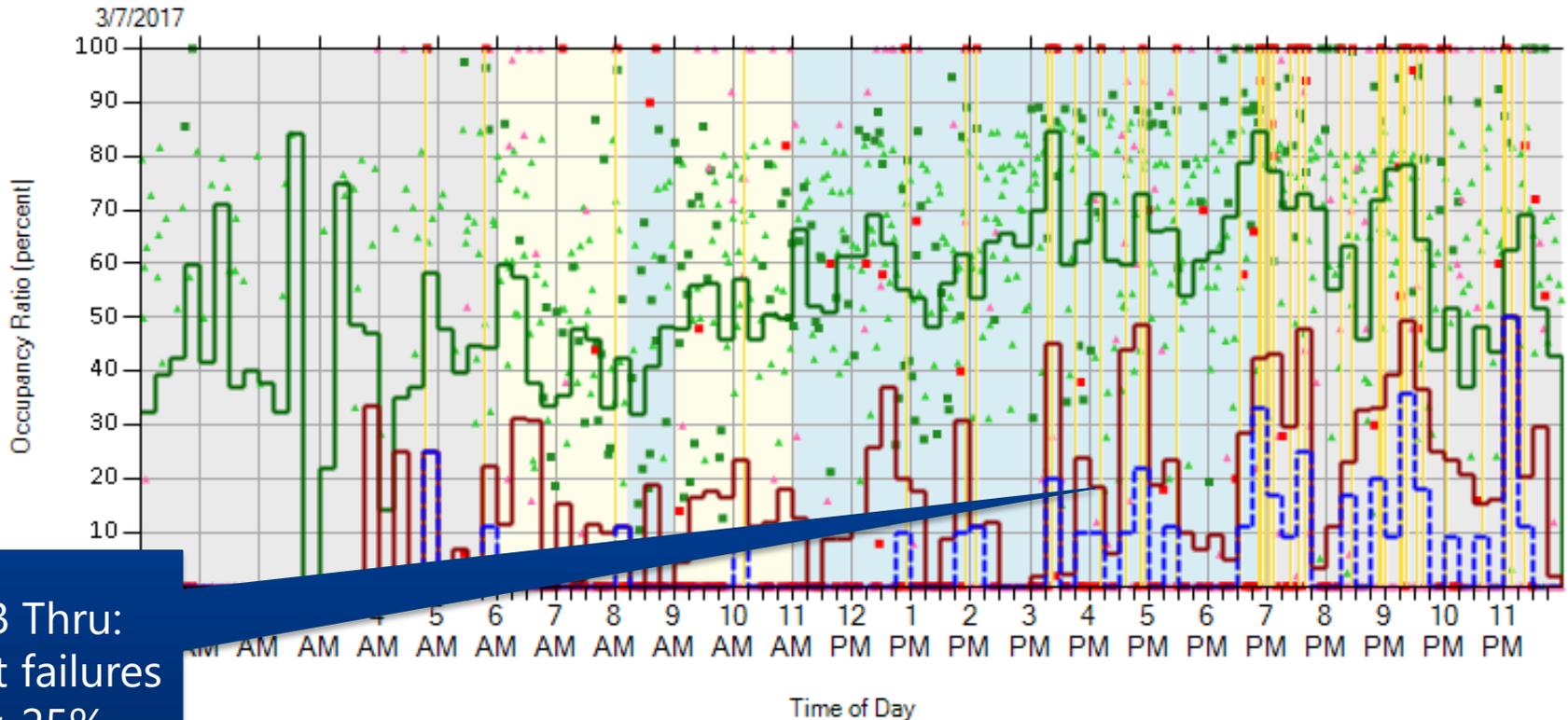
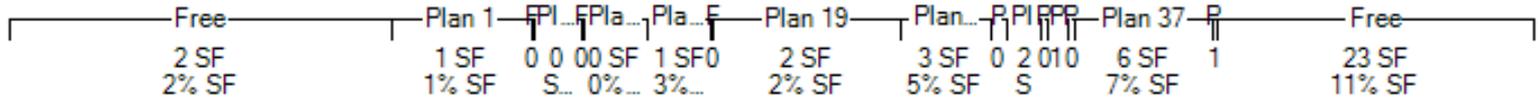
Split Failures  
Total split fails for the selected period = 6



# ATSPM: Example (Shippensburg, PA)



Split Failures  
Total split fails for the selected period = 42



Termination Type

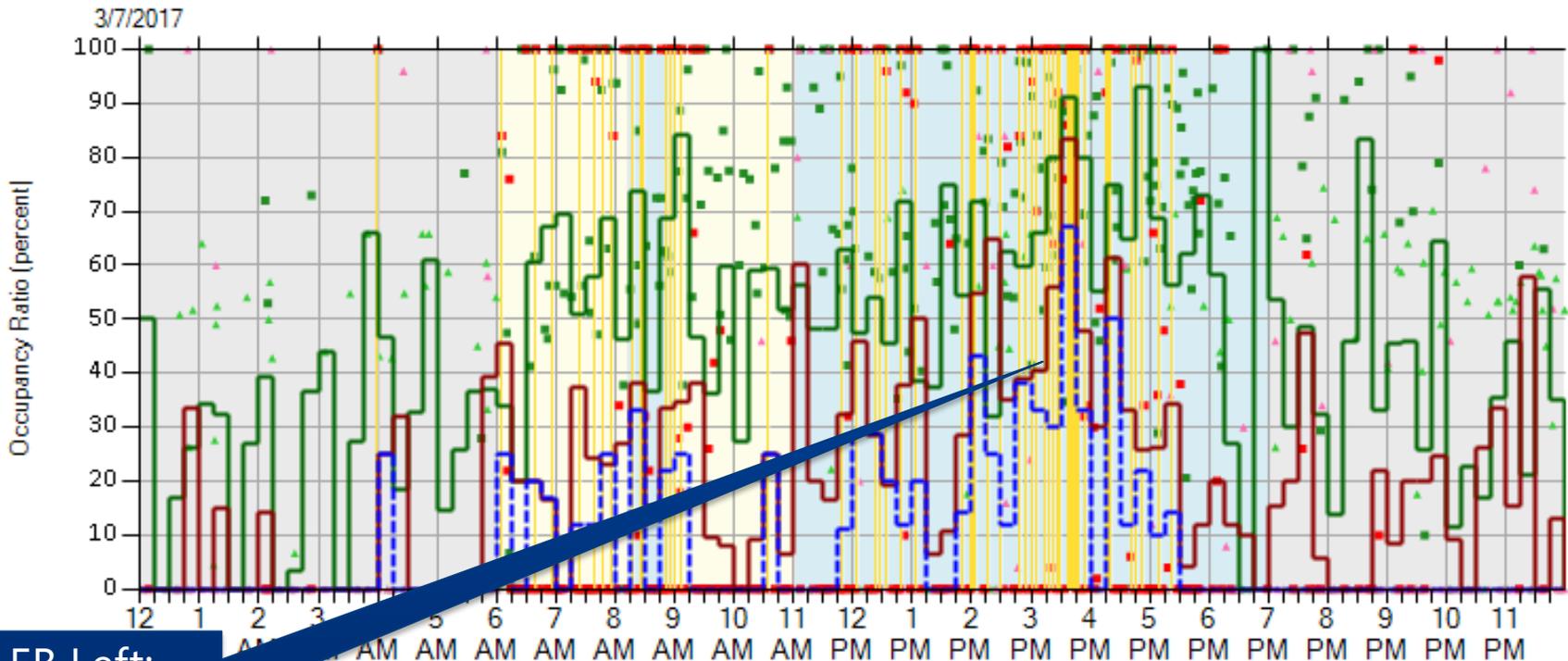
- ▲ GOR - GapOut
- GOR - ForceOff
- ▲ ROR - GapOut
- ROR - ForceOff
- SplitFail
- Avg. GOR
- Avg. ROR

# ATSPM: Example (Shippensburg, PA)



Split Failures  
Total split fails for the selected period = 57

Free	Plan 1	Plan 5	Plan 11	Plan 15	Plan 19	Plan 23	Plan 27	Plan 31	Plan 35	Plan 37	Free
1 SF	7 SF	0 SF	5 SF	11 SF	1 SF	10 SF	12 SF	5 SF	5 SF	3 SF	0 SF
2% SF	13% SF	0%	5%	4%	5%	14% SF	29%	5%	31%	5% SF	0% SF



EB Left:  
More split failures

- Termination Type
- GOR - GapOut
  - GOR - ForceOff
  - ROR - GapOut
  - ROR - ForceOff
  - SplitFail
  - Avg. GOR
  - Avg. ROR

# Automated Traffic Signal Performance Measures



**Steve Gault, P.E., PTOE**

Statewide Traffic Signal Operations Engineer

Pennsylvania Department of Transportation

717.787.6988

[sgault@pa.gov](mailto:sgault@pa.gov)

