

Leveraging Connected Infrastructure to Improve Transportation

Wednesday, February 28th, 2018

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WAYNE STATE
UNIVERSITY

Overview

Discussion Points

- Current Transportation Engineering Practices and Procedures
- Infrastructure Based Decision Making Tools
- Infrastructureless Decision Making Tools
- Combining, Optimizing, and The Future



Civil Engineering = Infrastructure



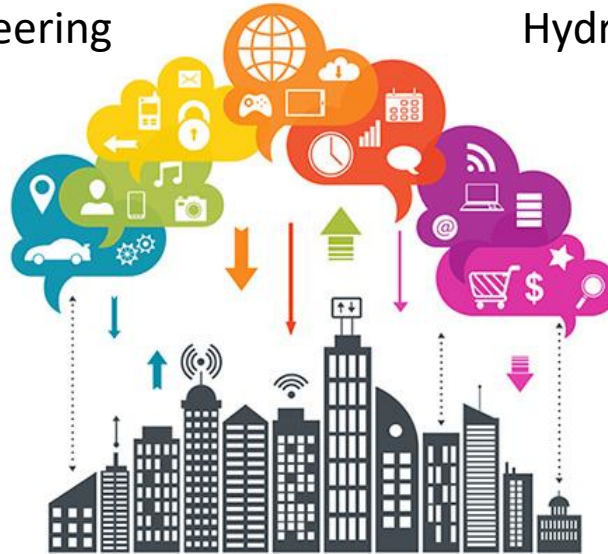
Structural Engineering



Hydraulic Engineering



Transportation Engineering



Construction Management



Geotechnical Engineering



Environmental Engineering

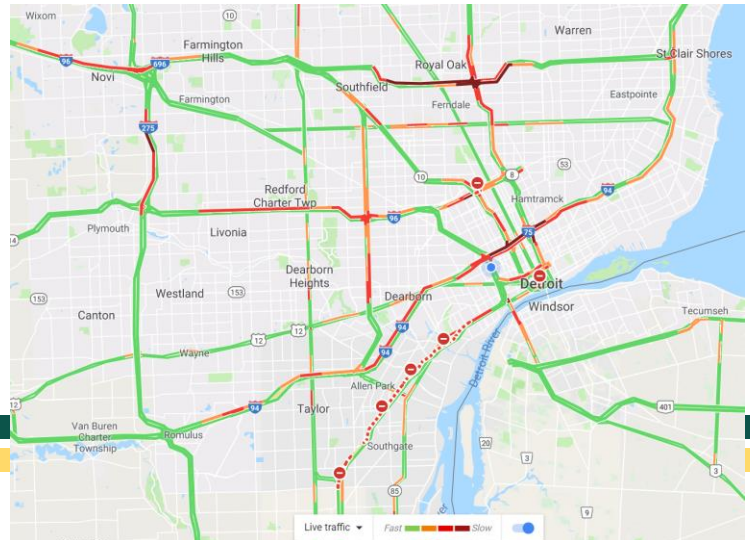
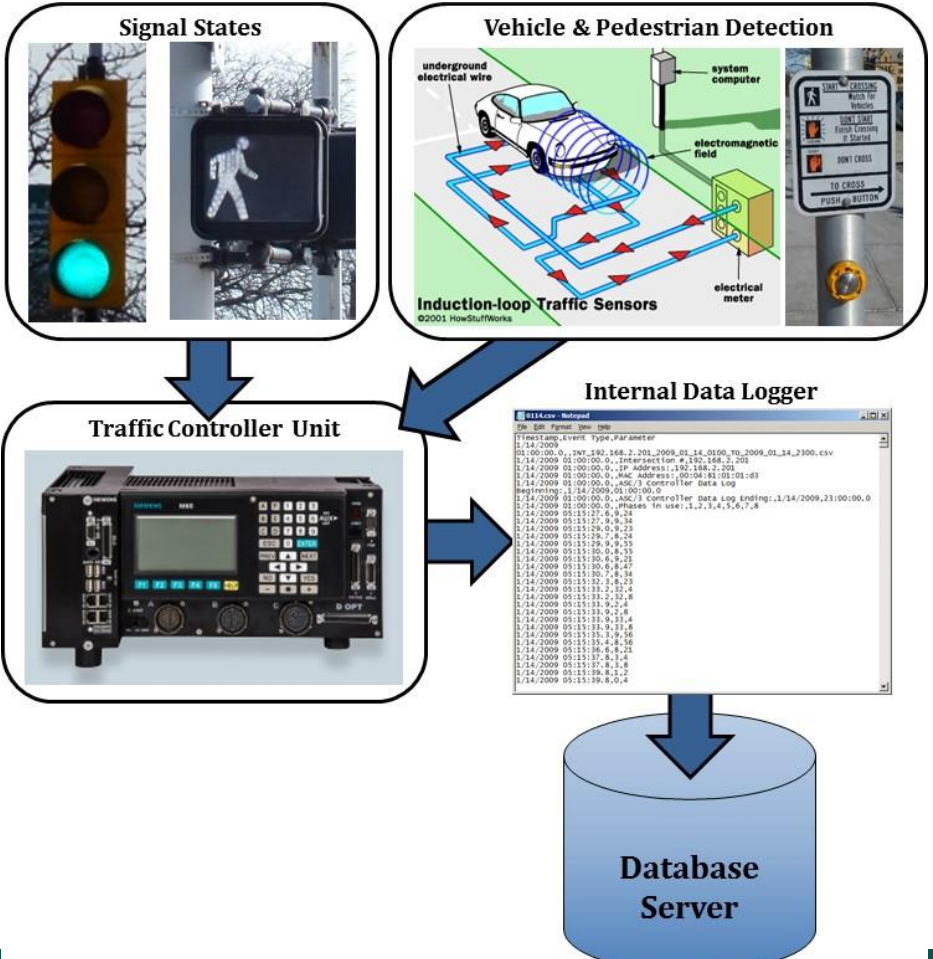
Current Data

High Res Signal Data

(Infrastructure Based)

Probe Data

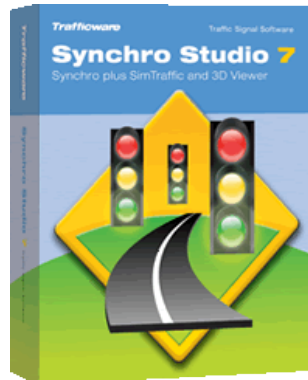
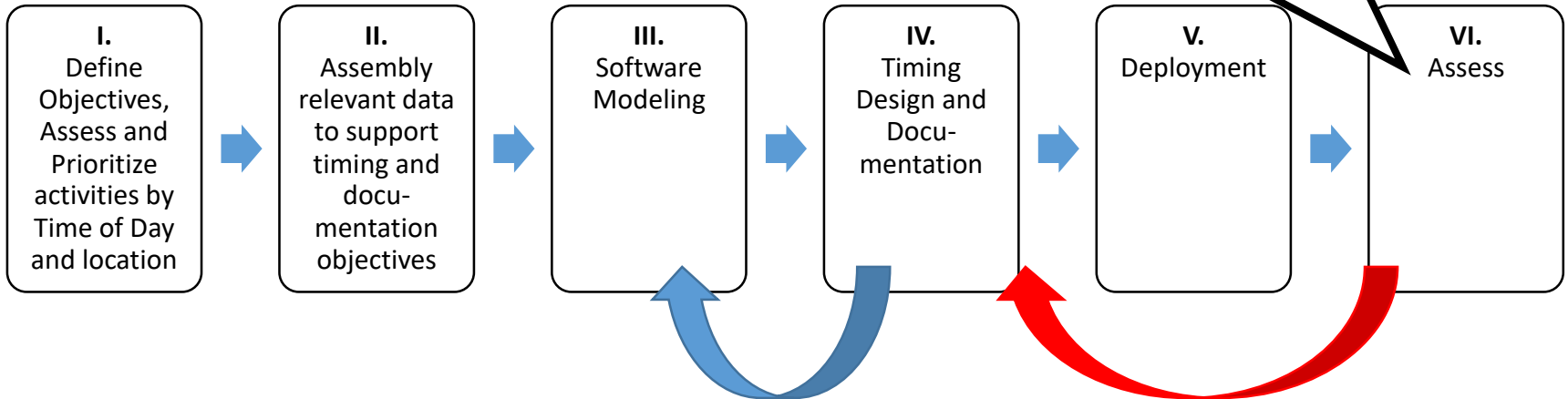
(Infrastructureless)



Signal Performance Measure Overview

Explanation

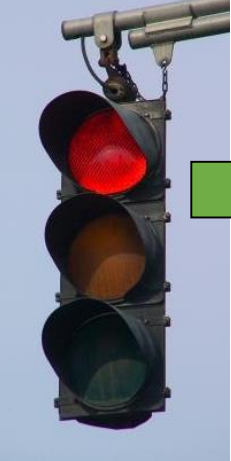
In a sensor based world if you can measure, we don't really need to model.



High Resolution Signal Controller Data

Explanation

Internal data logger –
0.1 second resolution

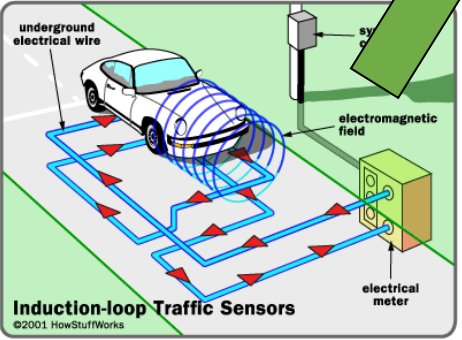


Signal States

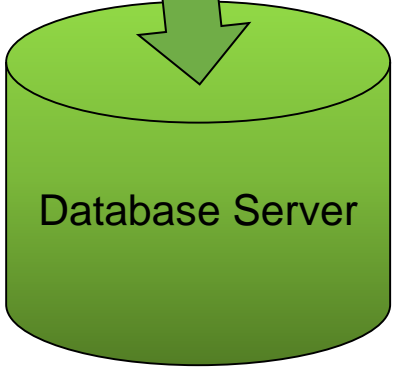


Controller Unit

```
0114.csv - Notepad
File Edit Format View Help
Timestamp,Event Type,Parameter
1/14/2009
01:00:00.0,INT,192.168.2.201_2009_01_14_0100_To_2009_01_14_2300.csv
1/14/2009 01:00:00.0,,Intersection #,192.168.2.201
1/14/2009 01:00:00.0,,IP Address:,192.168.2.201
1/14/2009 01:00:00.0,,MAC Address:,00:04:81:01:d3
1/14/2009 01:00:00.0,,ASC/3 Controller Data Log
Begin Time: 1/14/2009,01:00:00.0
1/14/2009 01:00:00.0,,Phases in use:,1,2,3,4,5,6,7,8
05:15:27.6,9,24
05:15:27.9,9,34
05:15:29.0,9,23
05:15:29.7,8,24
05:15:29.9,9,55
05:15:30.0,8,55
05:15:30.6,9,21
05:15:30.6,8,47
05:15:30.7,8,34
05:15:32.3,8,23
05:15:33.2,32,4
05:15:33.2,32,8
05:15:33.9,2,4
05:15:33.9,2,8
05:15:33.9,33,4
05:15:33.9,33,8
05:15:35.3,9,56
05:15:35.4,8,56
05:15:36.6,8,21
05:15:37.8,3,4
05:15:37.8,3,8
05:15:39.8,1,4
05:15:39.8,0,4
```



Vehicle Detections



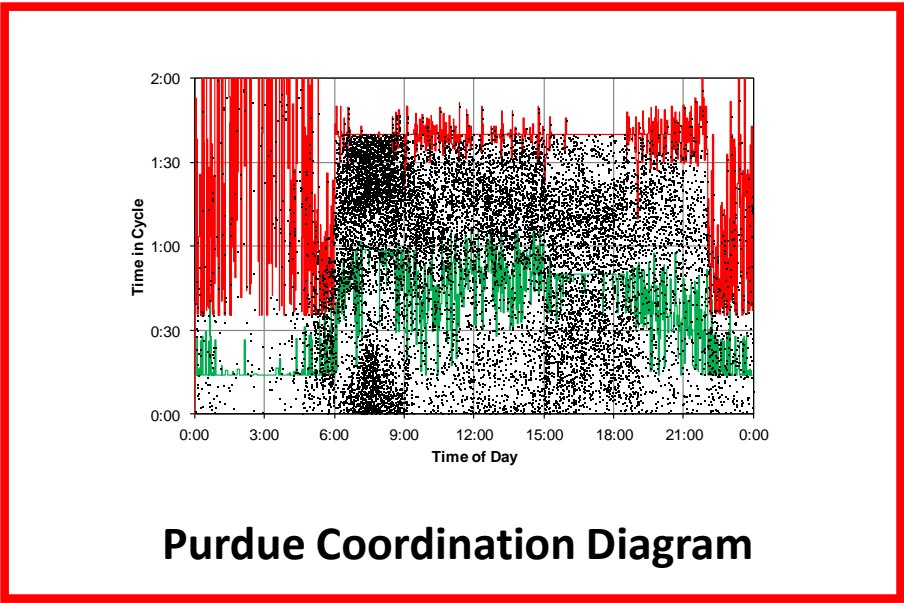
Relational Database

Database Server

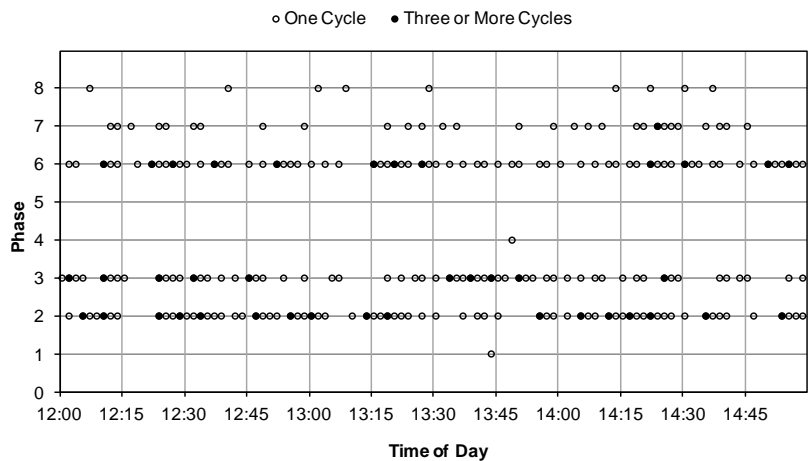


Purdue Performance Measures

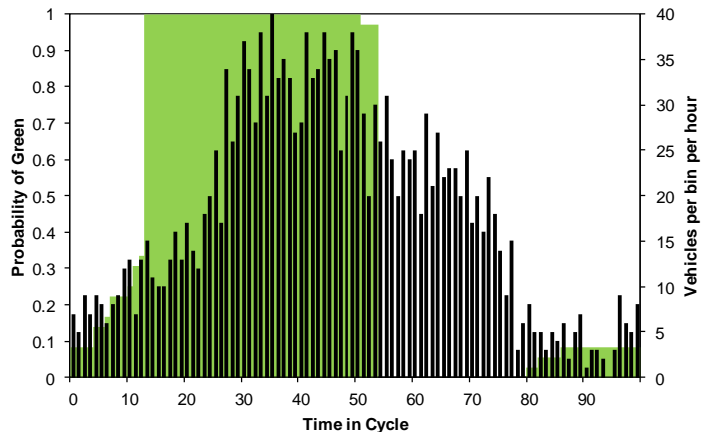
Performance Measures Developed using High-Res Controller Data



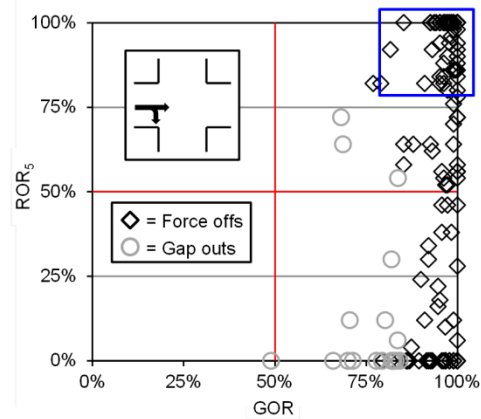
Purdue Coordination Diagram



Phase Termination Diagram



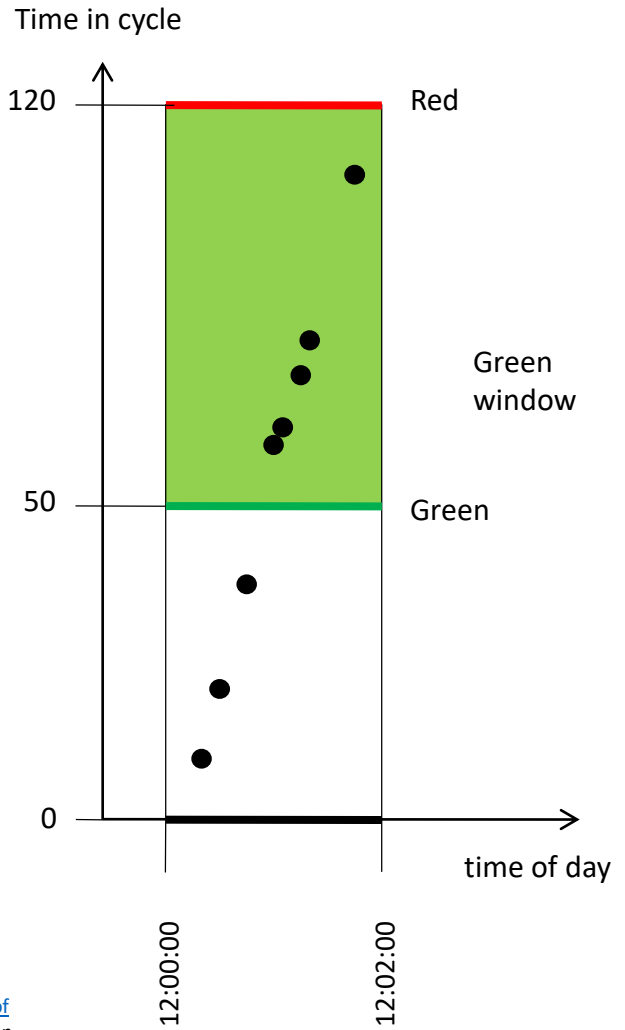
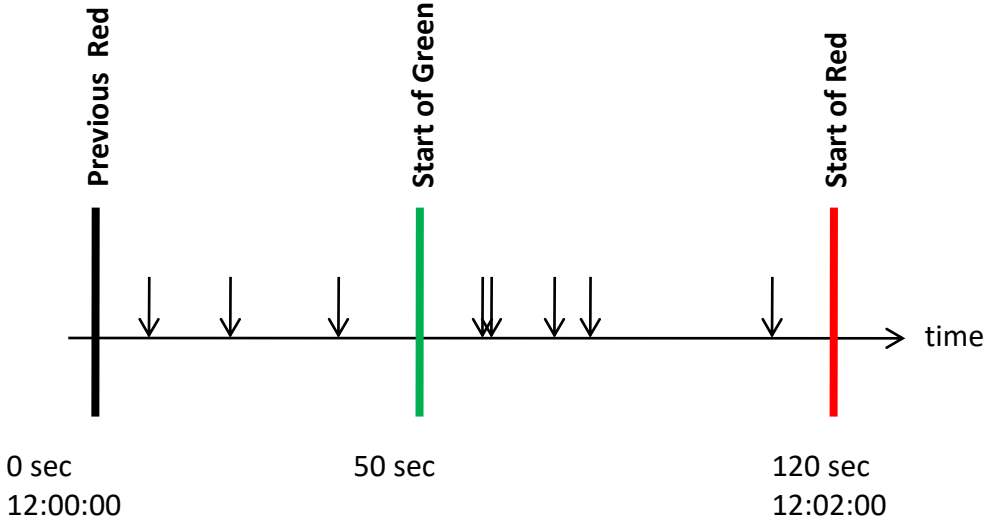
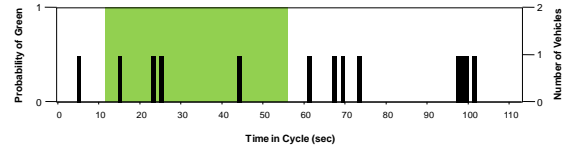
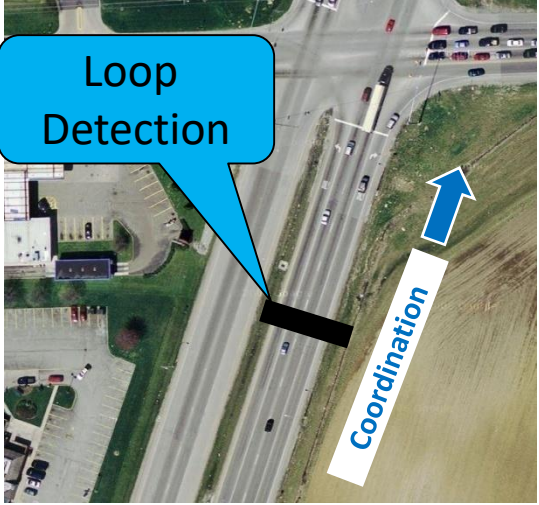
Flow Profile



ROR vs. GOR

Purdue Coordination Diagram

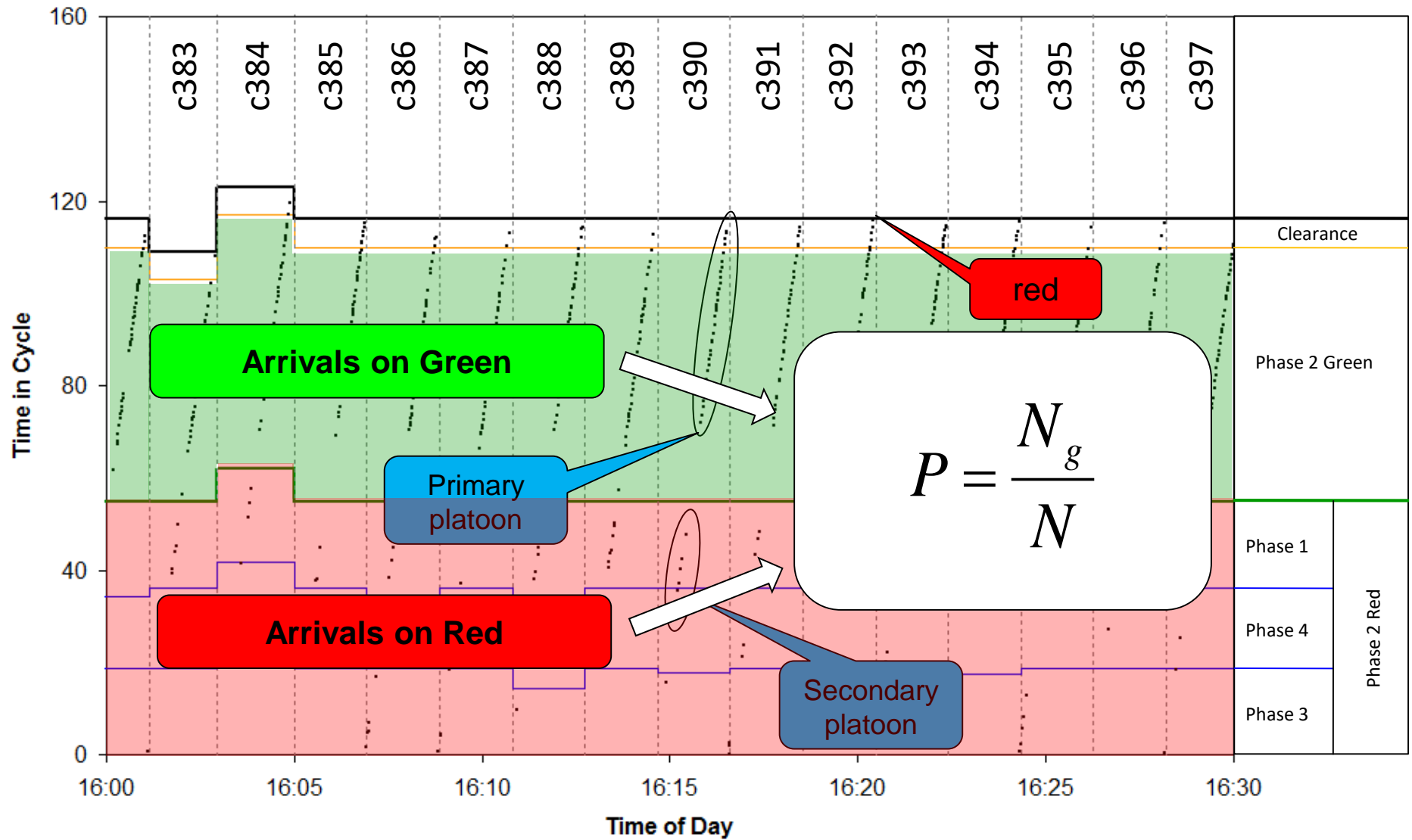
Concept



Day, C.M., Haseman, R., Premachandra, H., Brennan, T.M., Wasson, J.S., Sturdevant, J.R., and Bullock, D.M. (2010) [Evaluation of arterial signal coordination: methodologies for visualizing high-resolution event data and measuring travel time](#). *Transportation Research Record No. 2192*, 37-49.

Purdue Coordination Diagram

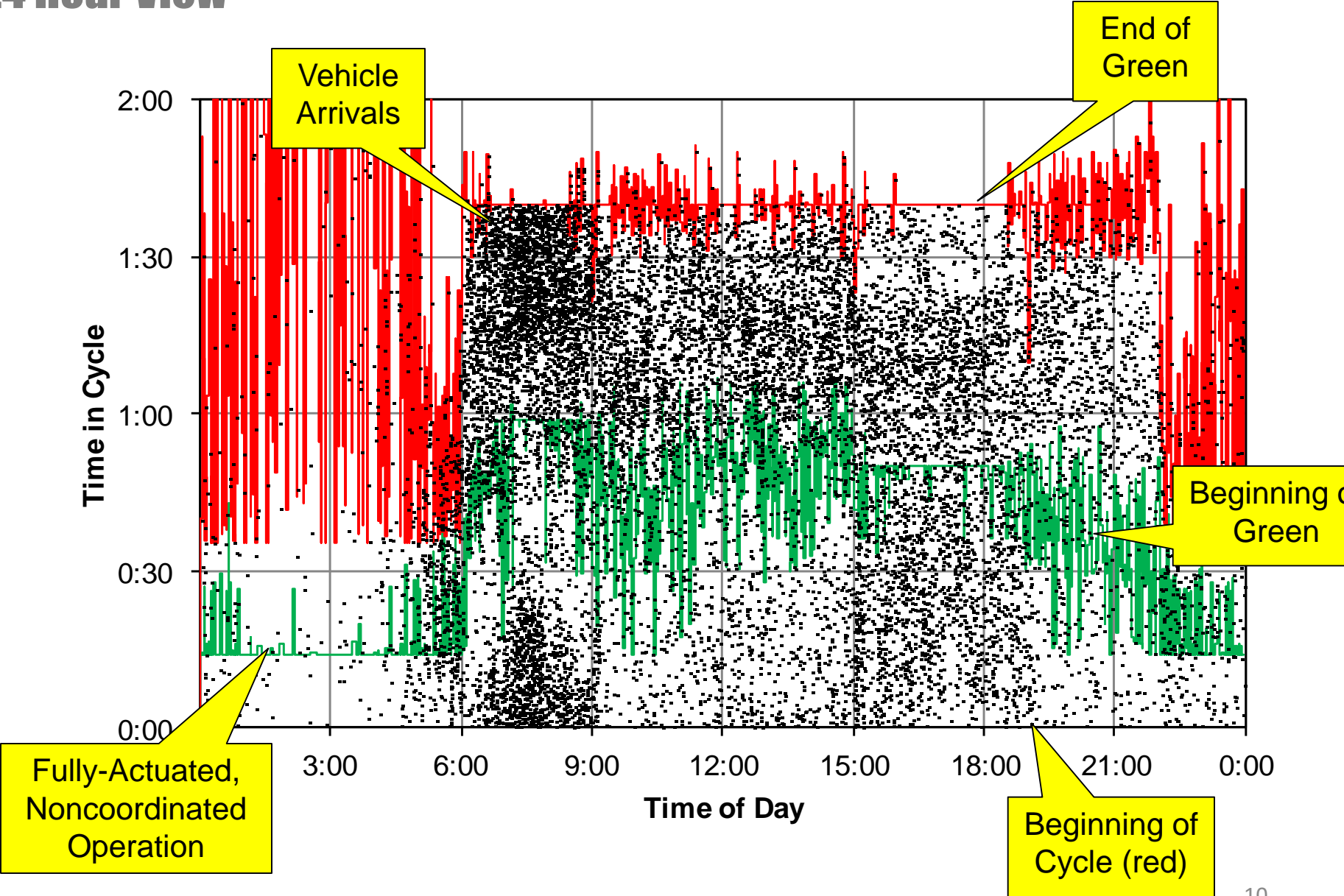
30 Minute View



Day, C.M., Haseman, R., Premachandra, H., Brennan, T.M., Wasson, J.S., Sturdevant, J.R., and Bullock, D.M. (2010) [Evaluation of arterial signal coordination: methodologies for visualizing high-resolution event data and measuring travel time](#). *Transportation Research Record No. 2192*, 37-49.

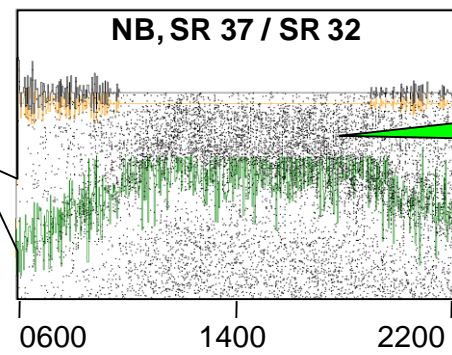
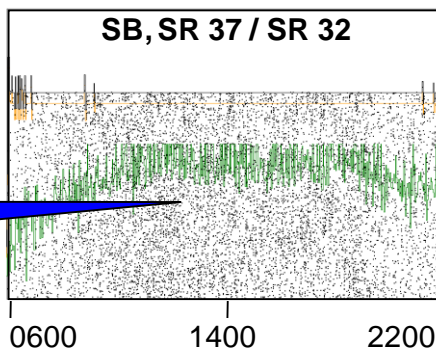
Purdue Coordination Diagram

24 Hour View



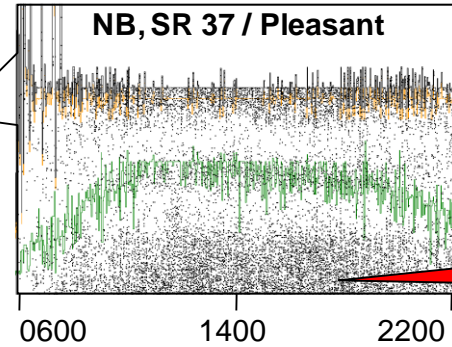
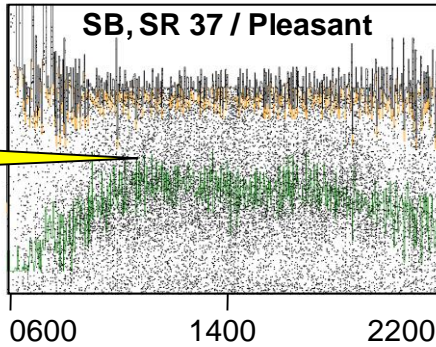
Before

Random



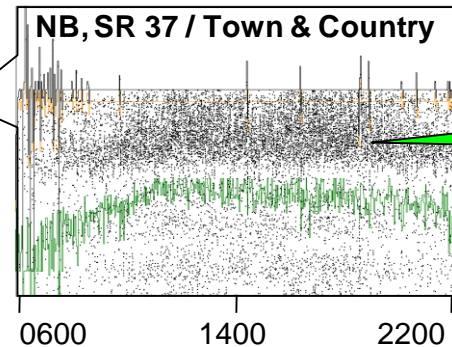
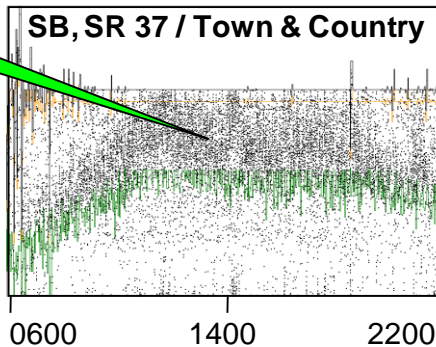
good

OK



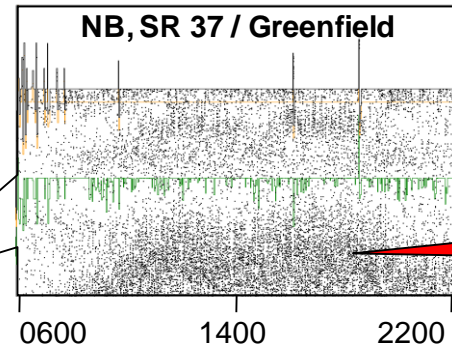
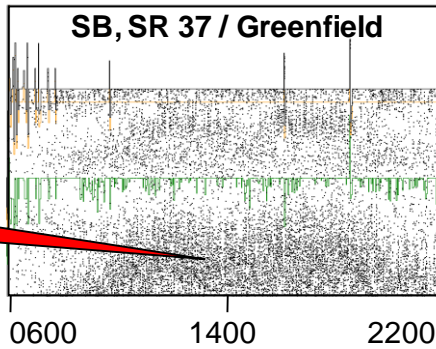
bad

good



good

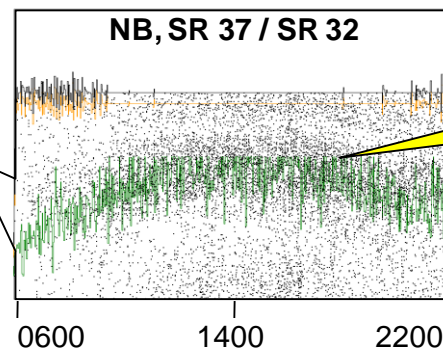
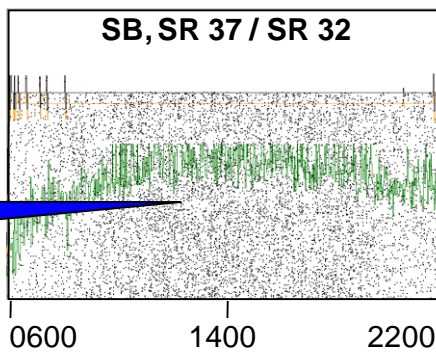
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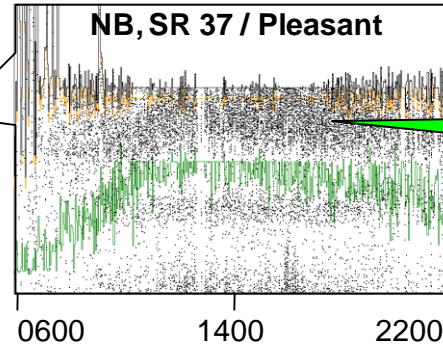
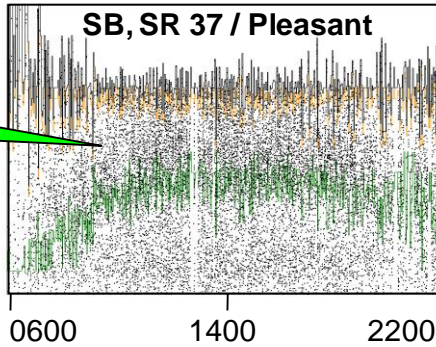
bad

After

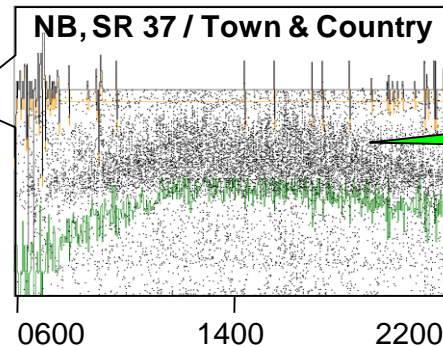
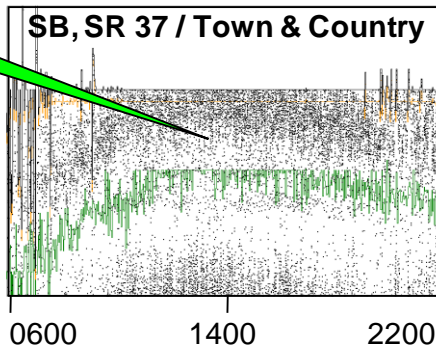
Random



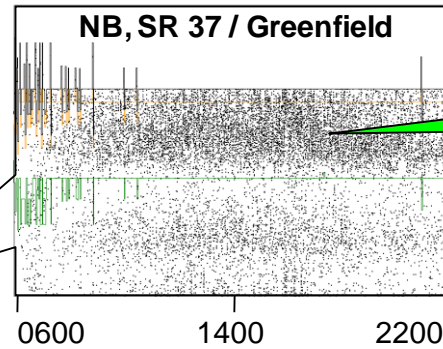
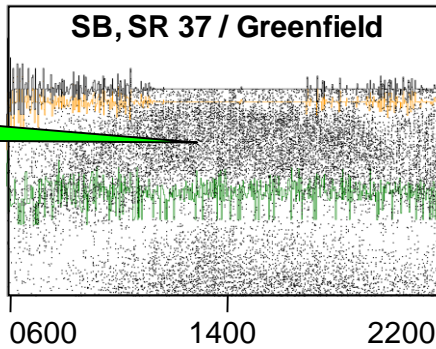
better



good



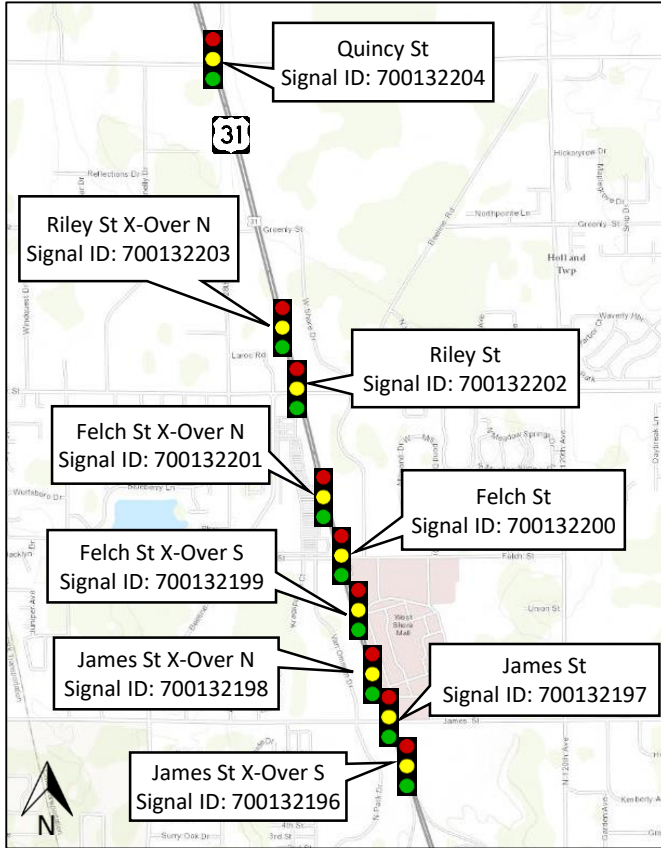
good



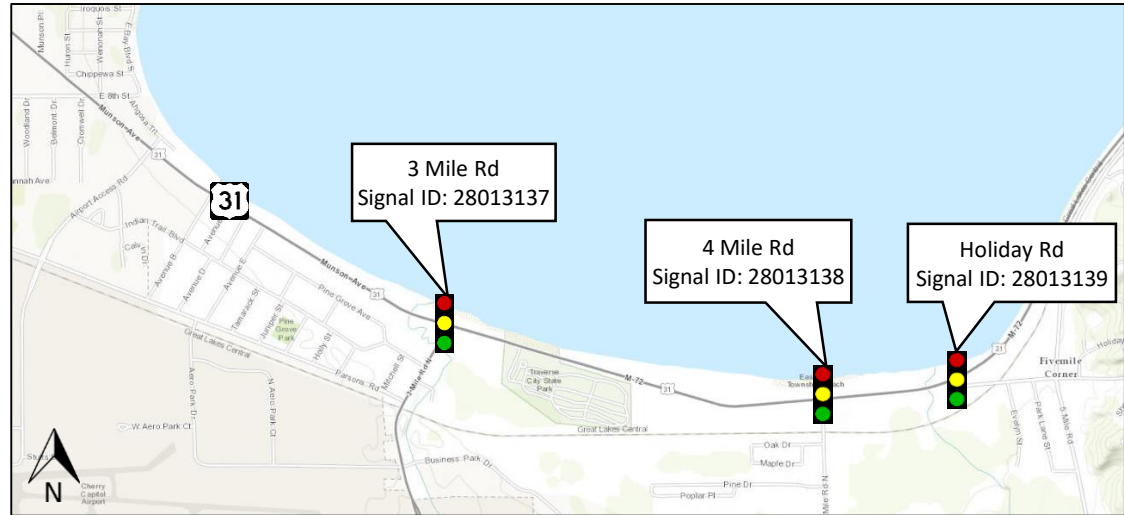
Day, C.M., Haseman, R., Premachandra, H., Brennan, T.M., Wasson, J.S., Sturdevant, J.R., and Bullock, D.M. (2010) [Evaluation of arterial signal coordination: methodologies for visualizing high-resolution event data and measuring travel time.](#) *Transportation Research Record No. 2192*, 37-49.

Corridor Overview Map

US-31 in Holland, MI



US-31 in Traverse City, MI



Signal Performance Measure Dashboard



Measures Reports Log Action Taken Links FAQ About

Register Log in

Signal

Signal Selection

Signal ID

Signal ID Press Enter to select signal

Signal List

Signal Map

Region

--Select Region--

Metric Type

--Select a Metric--

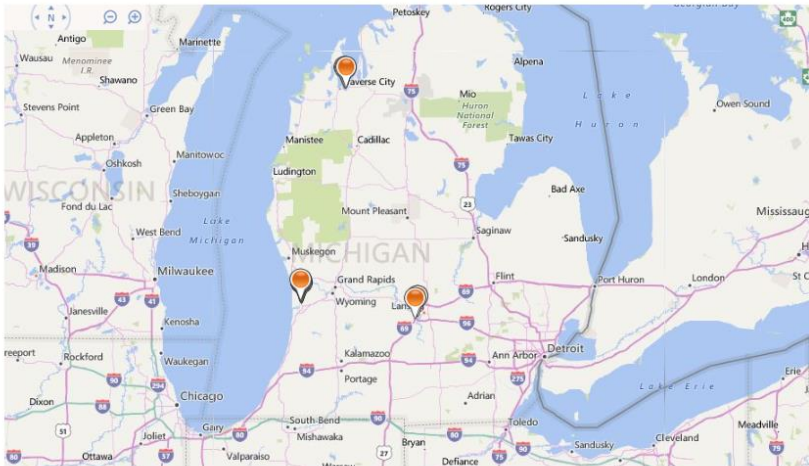


Chart Selection

Date Selection

Start Date

09/08/2017

12:00

AM

End Date

09/08/2017

11:59

PM

Reset Date

September 2017

Su	Mo	Tu	We	Th	Fr	Sa
					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

Create Chart

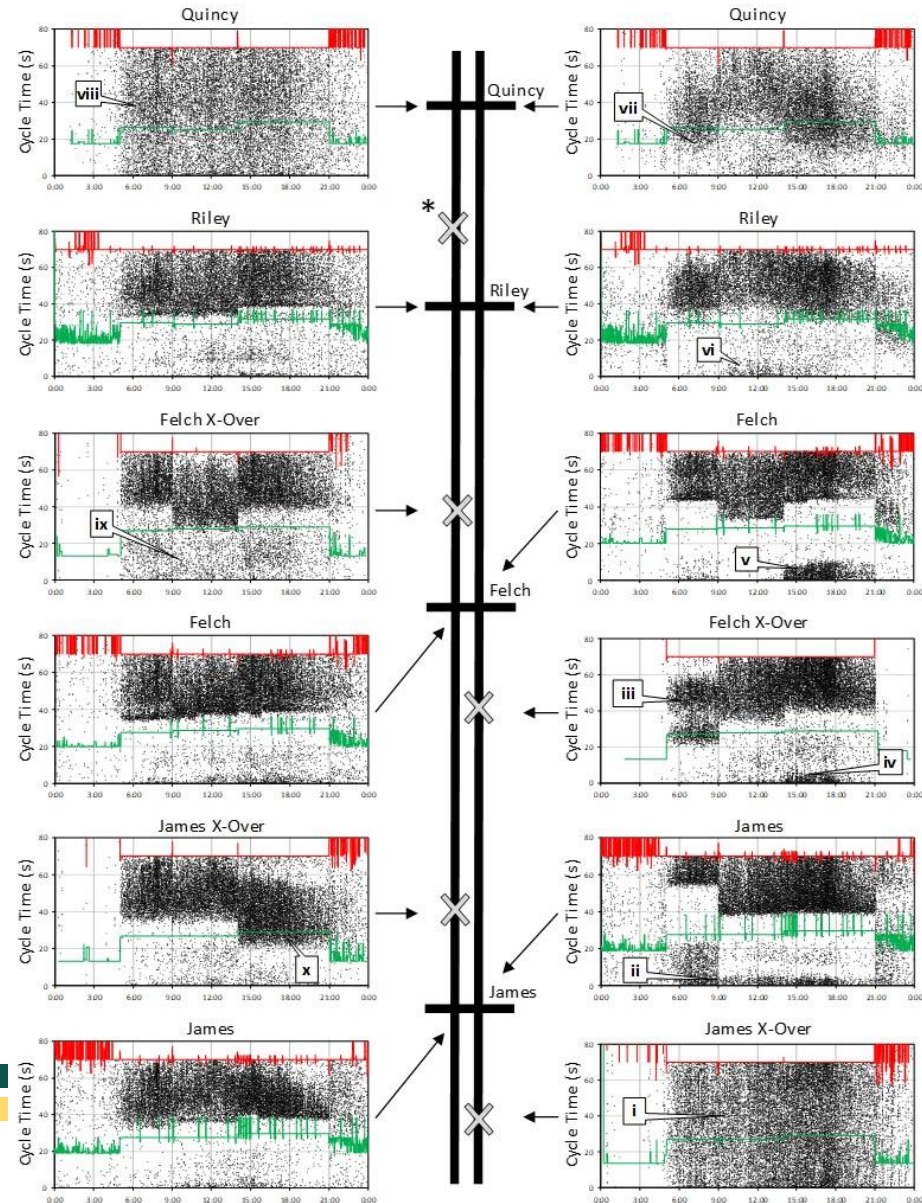


Baseline Performance Measures

Purdue Coordination Diagrams

SB Signals

NB Signals



Direction	Intersection	Percent On Green (POG)/			
		0500-0900 POG	0900-1400 POG	1400-2100 POG	All Day POG
NB	S. James X Over	64.10%	63.30%	61.70%	64.80%
NB	James St.	67.30%	92.10%	89.40%	82.40%
NB	S. Felch X. Over	86.50%	89.40%	86.20%	87.70%
NB	Felch St.	95.20%	93.60%	77.70%	87.20%
NB	Riley St.	94.90%	88.00%	87.00%	86.70%
NB	Quincy St.	71.80%	78.70%	50.30%	65.80%
SB	Quincy St.	64.00%	65.10%	59.30%	64.40%
SB	Riley St.	93.30%	87.60%	85.00%	87.30%
SB	N. Felch X. Over	82.70%	84.60%	83.40%	84.60%
SB	Felch St.	95.00%	91.80%	87.80%	90.60%
SB	N. James X Over	95.60%	89.00%	80.90%	88.00%
SB	James St.	96.90%	93.70%	94.00%	94.20%

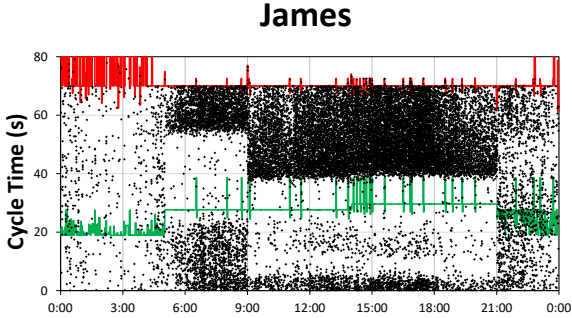
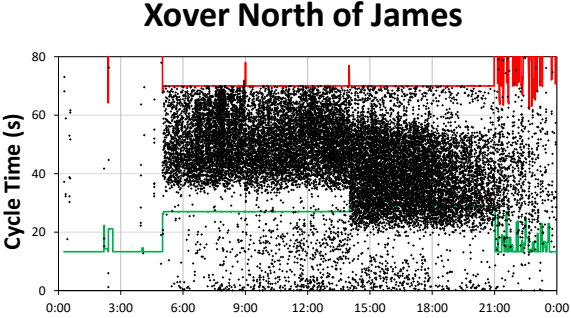


Baseline Performance Measures

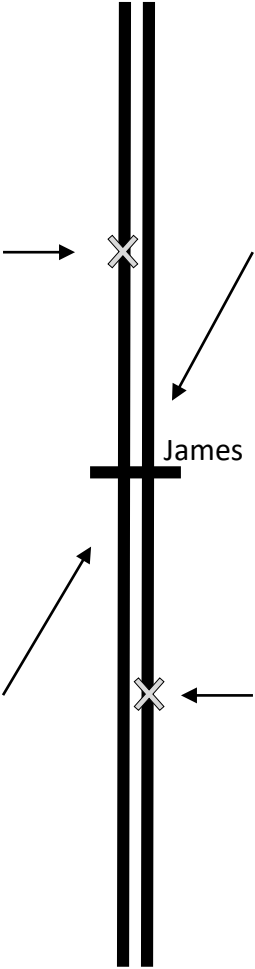
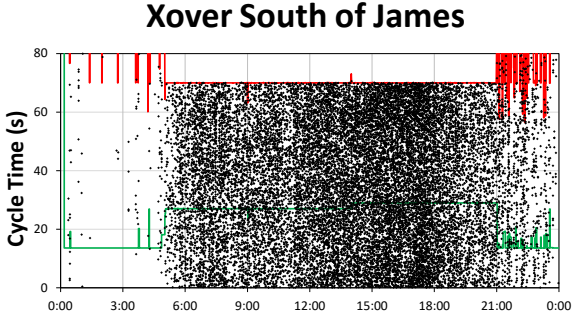
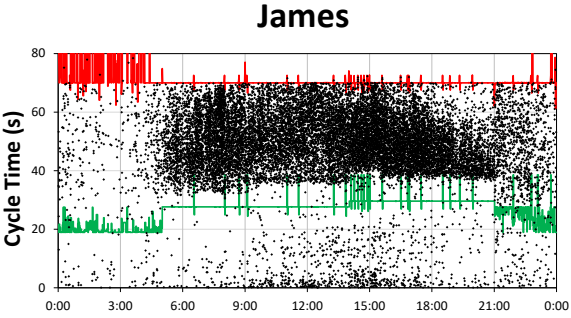
Purdue Coordination Diagrams

Holland, MI

SB Signals



NB Signals

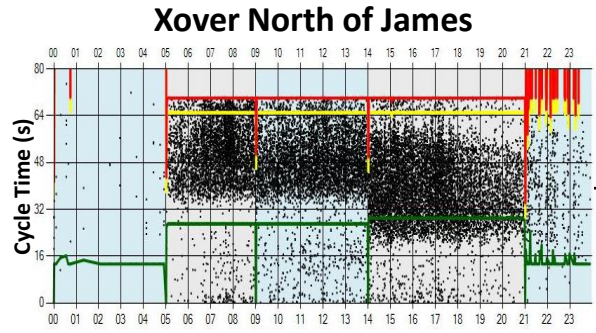


Offset Recalibration

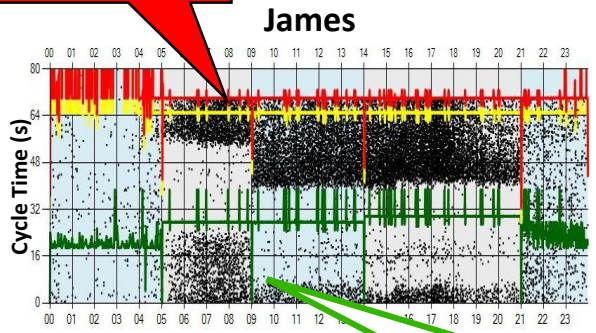
Before

Wednesday Sept. 6, 2017

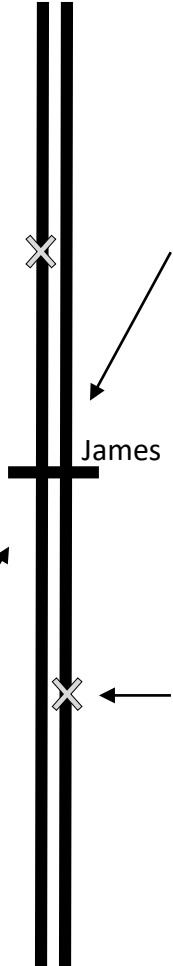
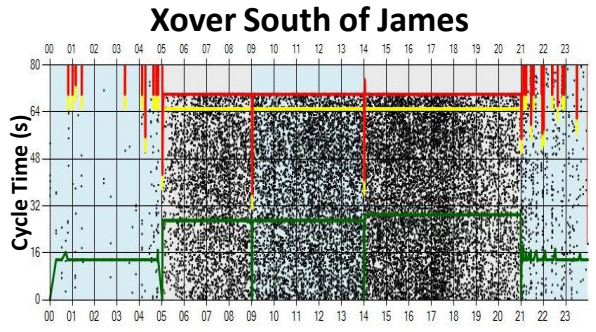
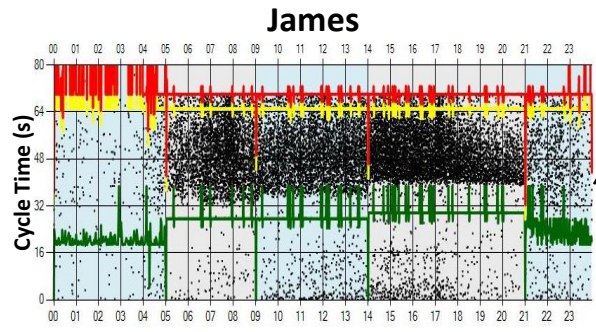
SB Signals



AOG = 61%



NB Signals



Holland, MI

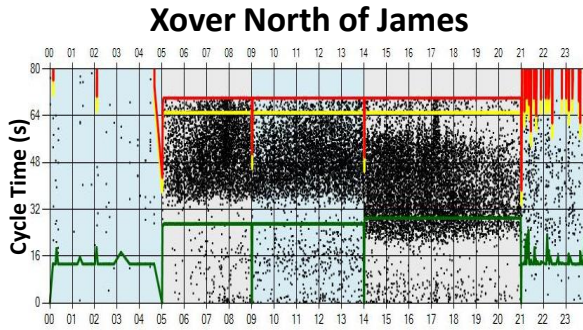


Offset Recalibration

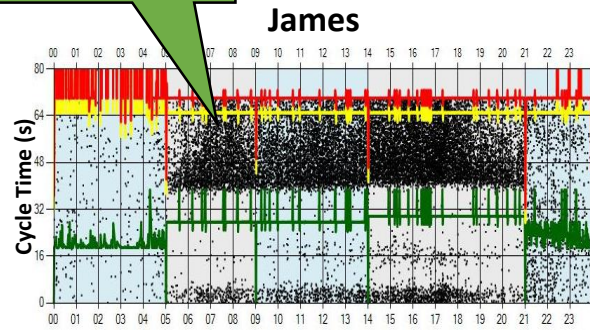
After

Wednesday Sept. 13, 2017

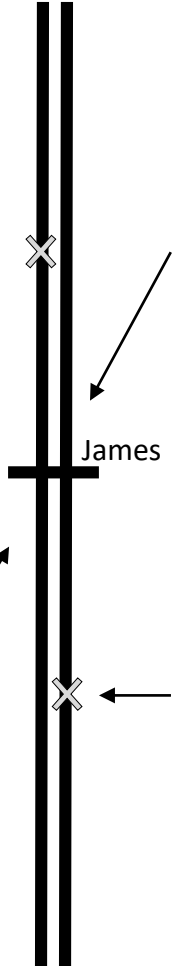
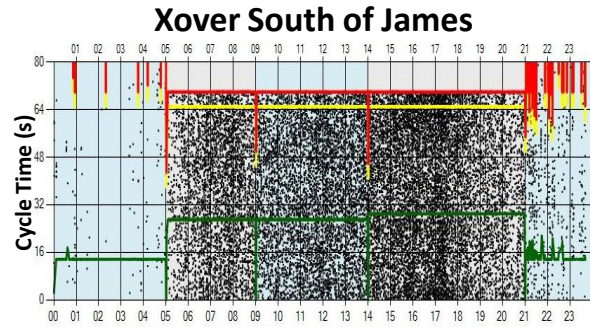
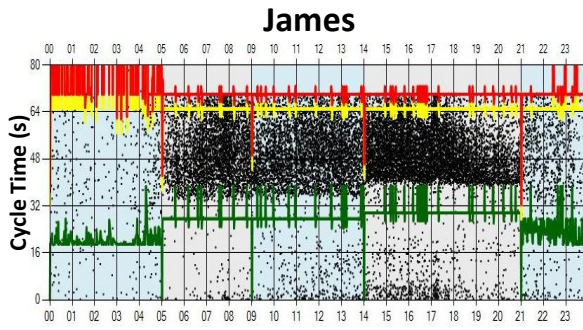
SB Signals



AOG = 91%



NB Signals



Holland, MI

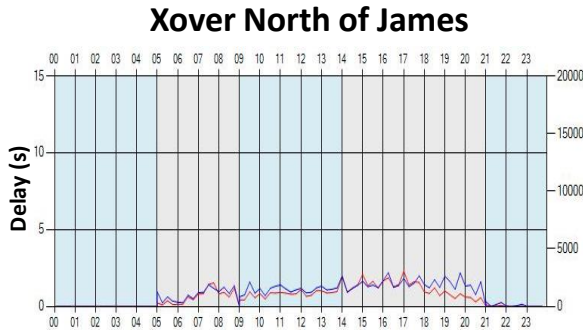


Offset Recalibration

Before

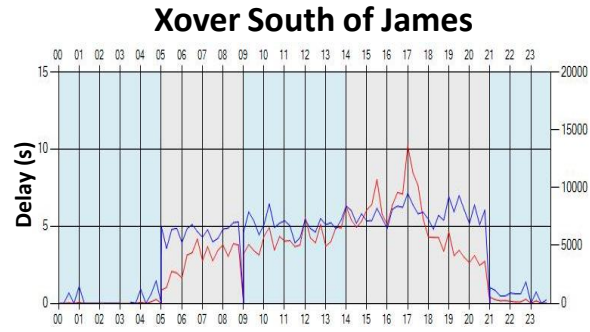
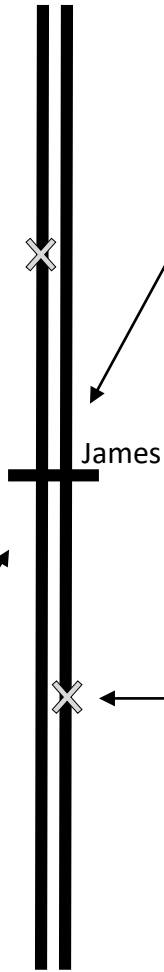
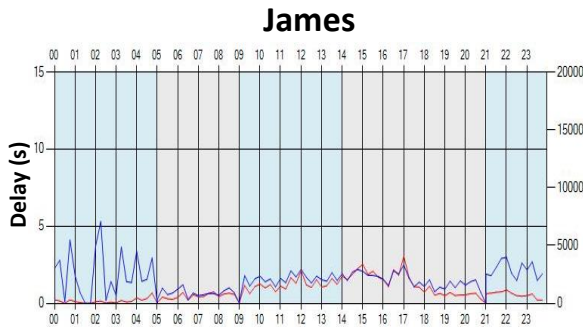
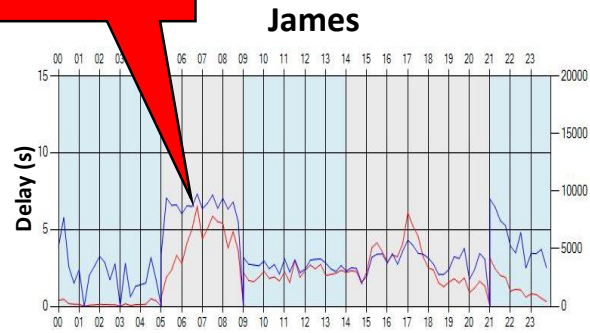
Wednesday Sept. 6, 2017

SB Signals



AD = 7 s
TD = 393 min

NB Signals



Holland, MI

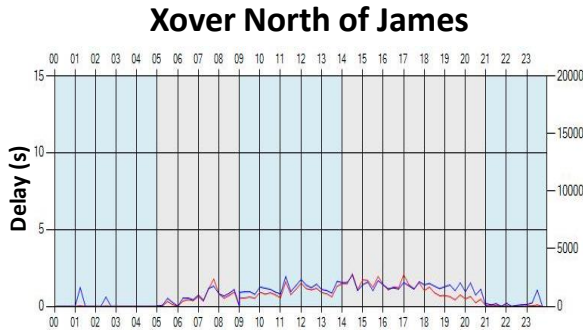


Offset Recalibration

After

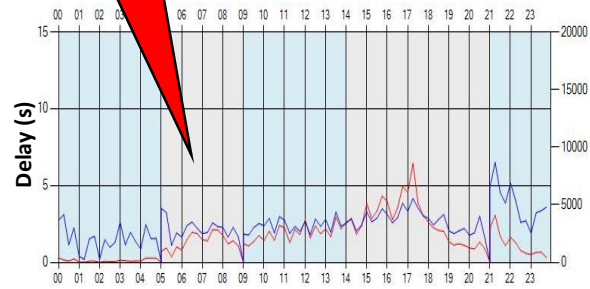
Wednesday Sept. 13, 2017

SB Signals

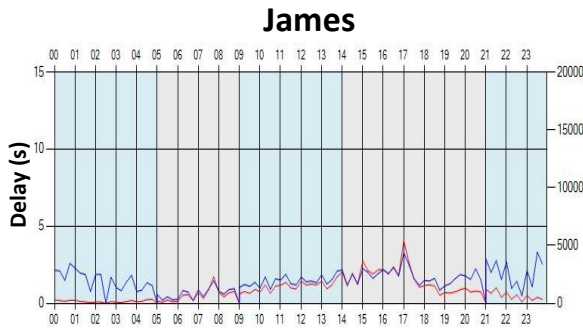


AD = 2 s
TD = 133 min

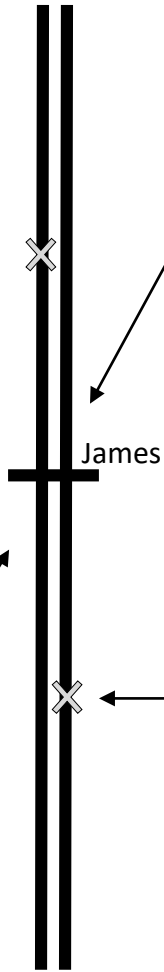
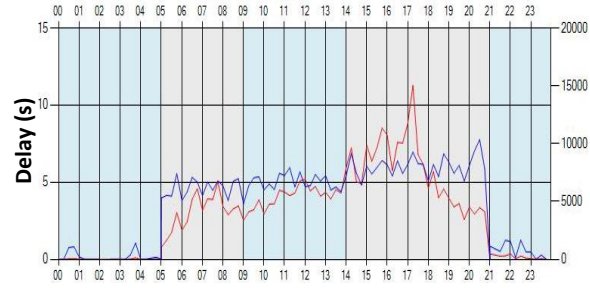
James



NB Signals



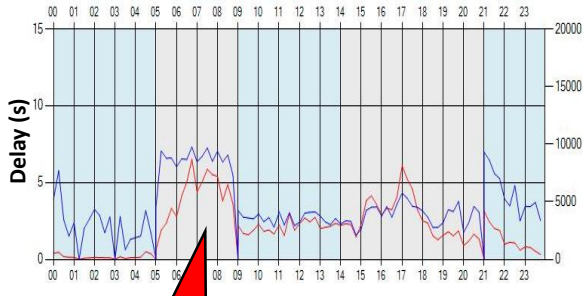
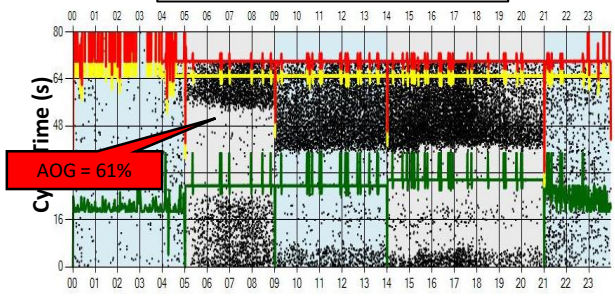
Xover South of James



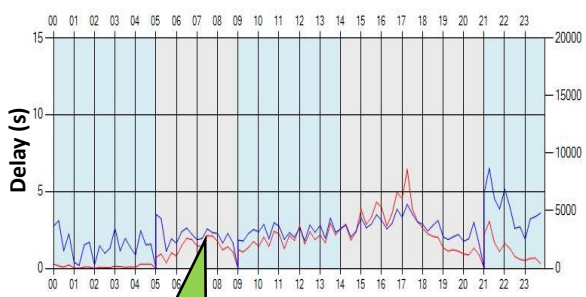
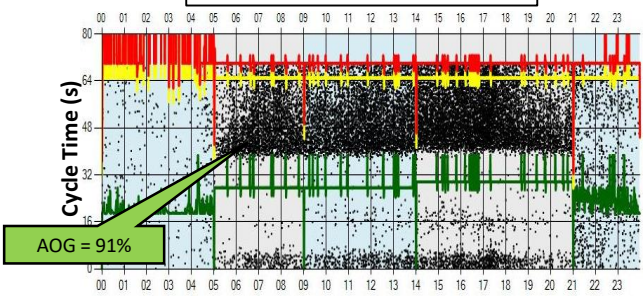
Offset Recalibration

After

Wednesday Sept. 6, 2017



Wednesday Sept. 13, 2017



Time Period	Delay Savings (hrs)	Delay Saving Cost (\$)
1 Week	21.6	\$478
1 Month	90.5	\$2000
1 Year	1086.4	\$23,996


Holland, MI

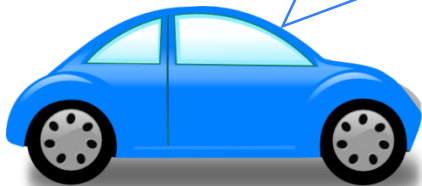



Probe Vehicle Data

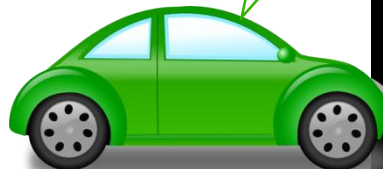
History

- GPS Probe Vehicles – 1990s
- Bluetooth Matching – 2008

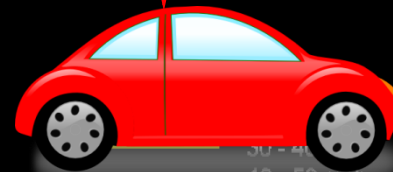
 65:E0:3E:17:62:50



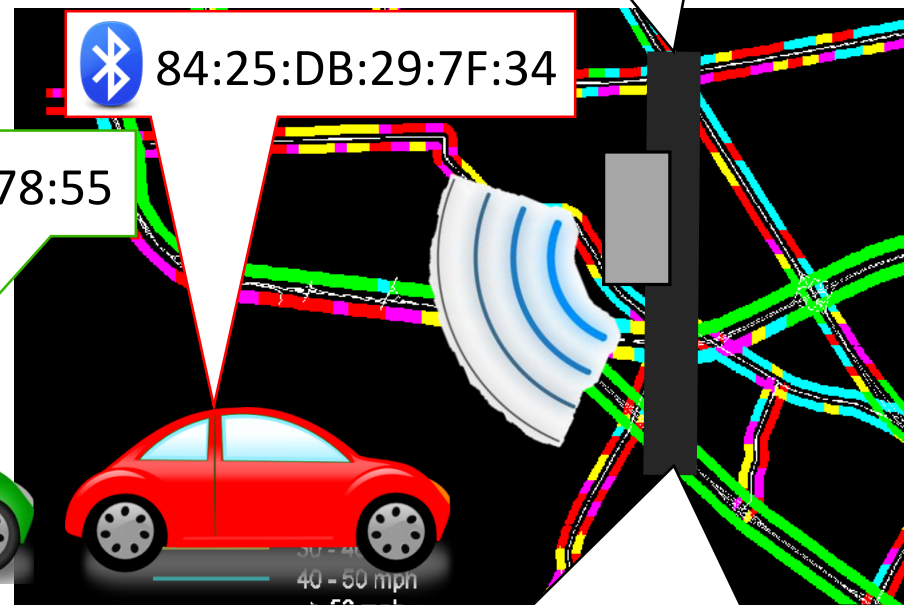
 00:08:E0:3B:78:55



 84:25:DB:29:7F:34



Data	
MAC Address	Timestamp
84:25:DB:29:7F:34	9/8/2013 14:24:32
00:08:E0:3B:78:55	9/8/2013 14:24:35
65:E0:3E:17:62:50	9/8/2013 14:24:39

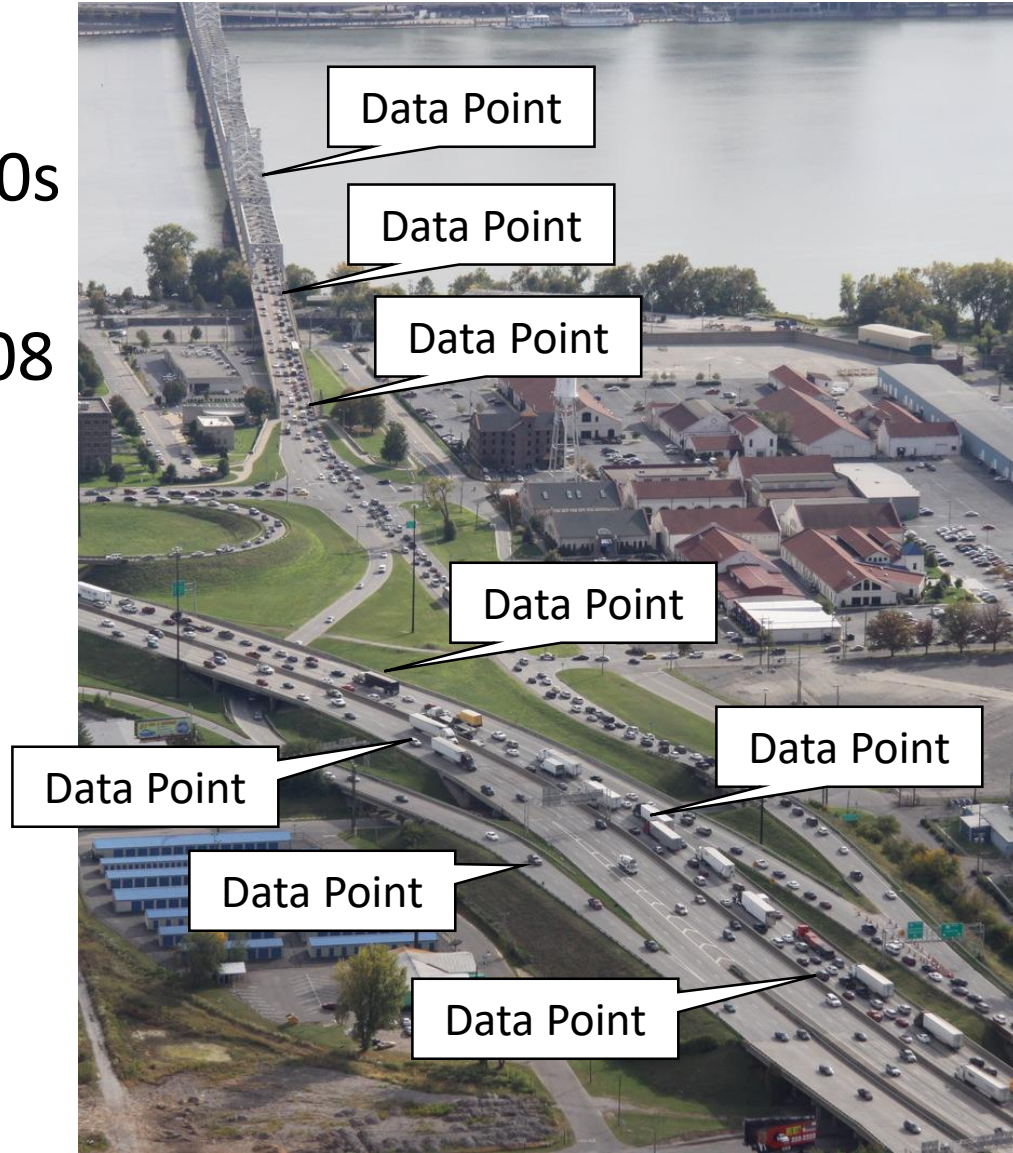
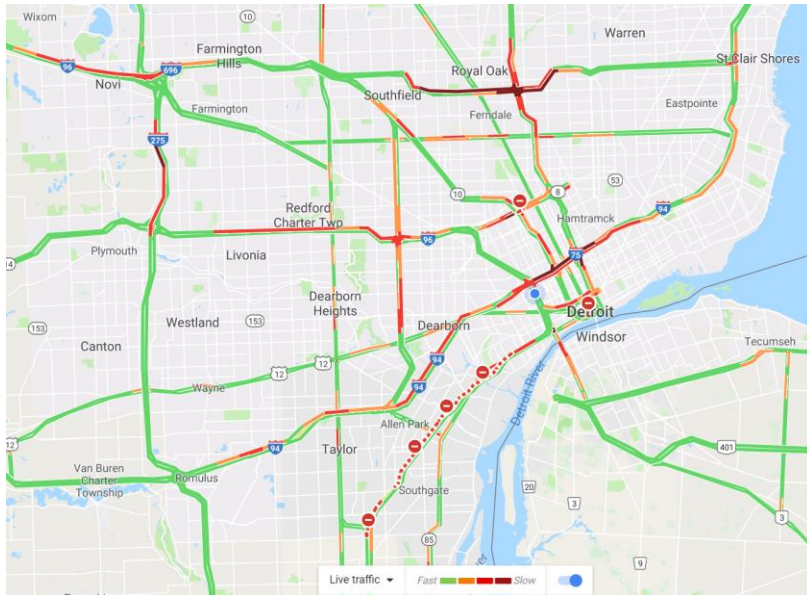


Pole Mounted Bluetooth Monitoring Station

Probe Vehicle Data

History

- GPS Probe Vehicles – 1990s
- Bluetooth Matching – 2008
- Crowdsourcing – 2010s



What is Crowd Sourced Data

Explanation

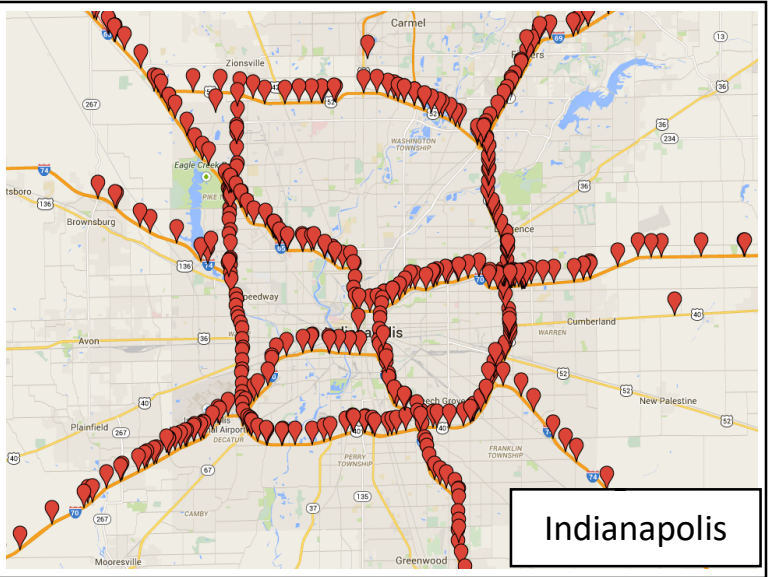
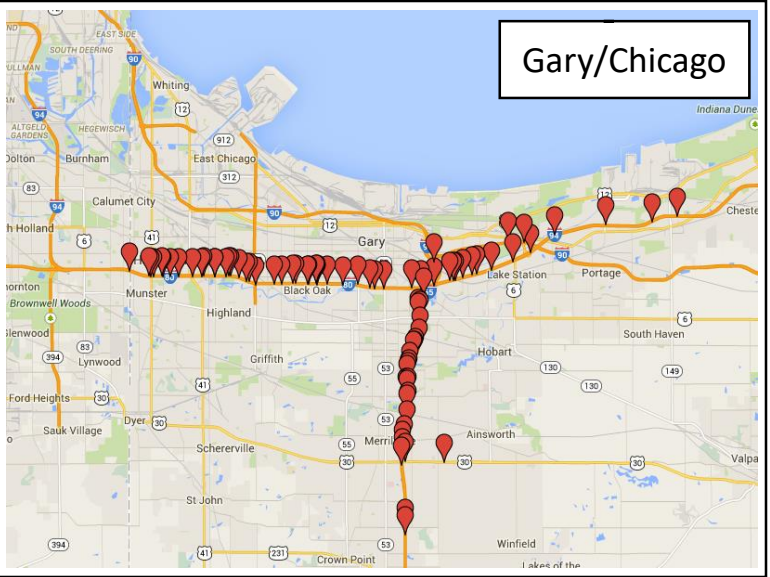
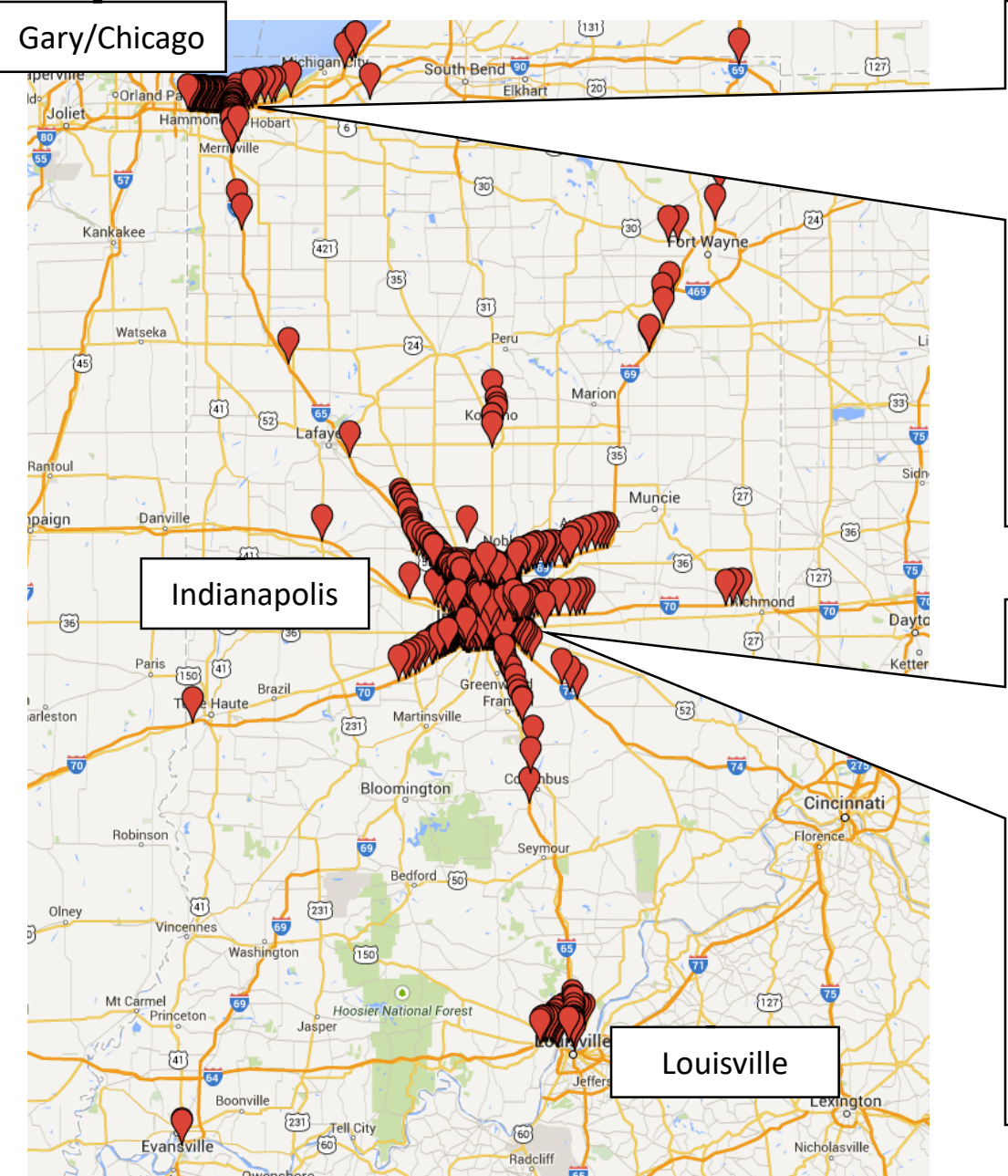


Over 20,000 Segments in
the state of Michigan

A record consists of a Segment ID,
a Time, and a Speed

Tmc	TimeDate	Speed
107+04800	5/1/2013 11:00	63
107+04800	5/1/2013 11:01	63
107+04800	5/1/2013 11:02	63
107+04800	5/1/2013 11:03	63
107+04800	5/1/2013 11:04	64
107+04800	5/1/2013 11:05	63
107+04800	5/1/2013 11:06	63
107+04800	5/1/2013 11:07	62
107+04800	5/1/2013 11:08	62
107+04800	5/1/2013 11:09	63
107+04800	5/1/2013 11:10	63
107+04800	5/1/2013 11:11	62
107+04800	5/1/2013 11:12	62
107+04800	5/1/2013 11:13	62
107+04800	5/1/2013 11:14	61 ²⁴

INDOT ITS INFRASTRUCTURE



Mobility Report Performance Measures

Definitions

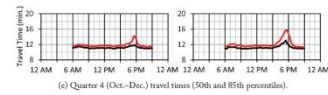
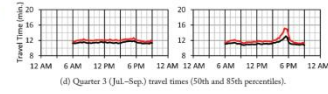
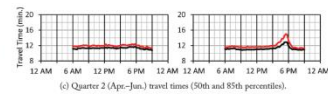
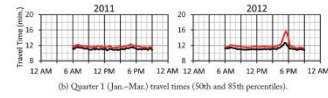
Performance Measure	Definition	Equation
Congestion Hours	Hours < 45 mph	$CH(S, T) = 0.25 \sum_{i \in S} \sum_{j \in T} \delta_{ij}$
Distance-Weighted Congestion Hours	Hours < 45 mph multiplied by the Segment Length	$DWCH(S, T) = 0.25 \sum_{i \in S} \sum_{j \in T} \delta_{ij} x_i$
Congestion Index	Total number of congestion hours along an interstate divided by the total length of the interstate.	$CH(S, T) = (0.25 \sum_{i \in S} \sum_{j \in T} \delta_{ij}) / \sum x_i$
Speed Profile	The number of congestion hours grouped by speed ranges.	$SP(S, T) = 0.25 \sum_{i \in S} \sum_{j \in T} \delta_{ij}$
Speed Deficit	The difference between the 45 mph congestion threshold and the actual observed speed.	$SD_{ij} = \max(0, v_E - v_{ij})$
Travel Time Deficit	The number of hours of delay occurring where speeds are below the 45 mph congestion threshold.	$TTD(S, T) = \sum_{i \in S} \sum_{j \in T} \left(\frac{\delta_{ij}}{\sum v_{ij}} - \frac{1}{v_e} \right) x_i$

Visual Performance Metrics

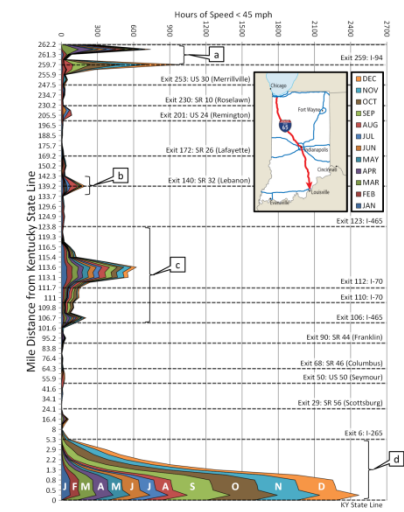
Summary

1

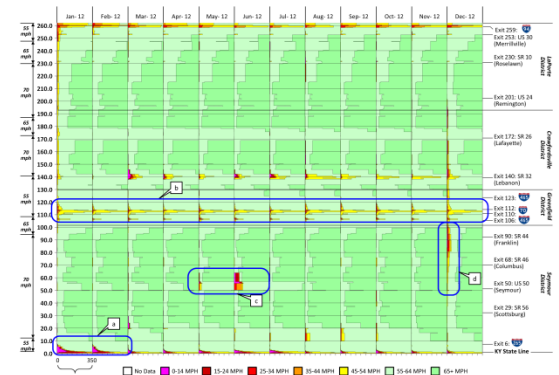
Roadway: SR 37 SB
 Year: 2011/2012
 Start: I-465
 End: SR 144
 Length: 9.72 miles
 Lanes: 2-3
 Min. AADT: 28,920



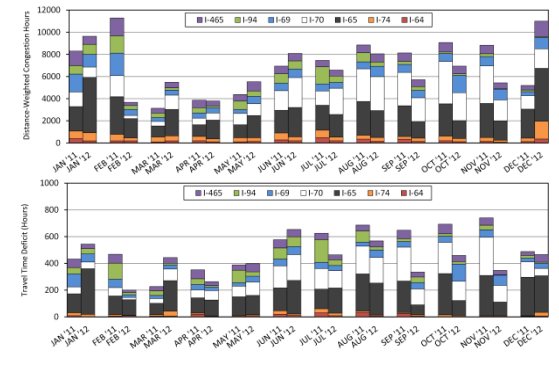
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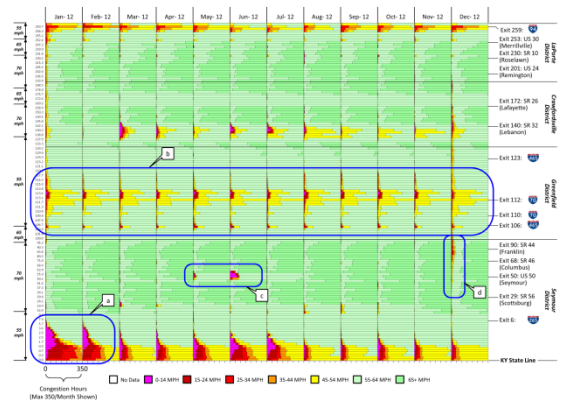
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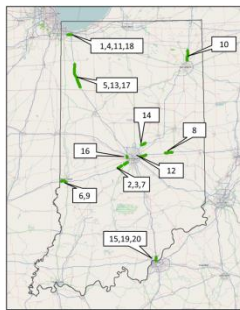
6



3

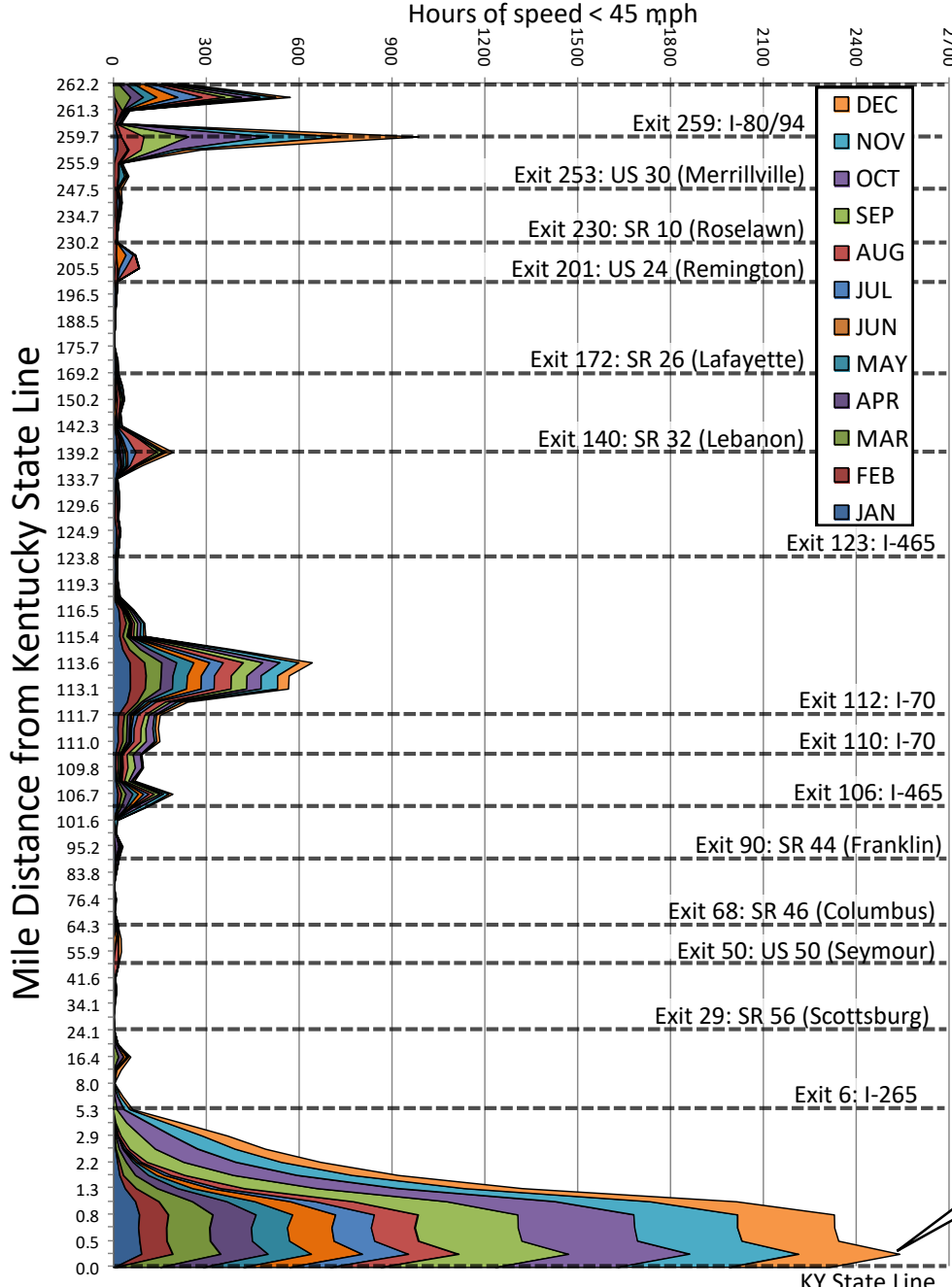


5



RANK	INTERSTATE	LENGTH (miles)	SEGMENTS (mile markers)	2011 ITD (hours)	2012 ITD (hours)	TTD Difference (2011-2012)
1	I-94 E	1.80	6.9 to 8.7	153.6	11.8	141.8
2	I-70 W	4.04	72.4 to 68.4	118.8	1.9	116.9
3	I-70 W	4.55	65.5 to 60.5	143.4	39.0	104.4
4	I-94 E	0.74	8.7 to 9.5	108.1	8.4	99.7
5	I-65 N	7.14	205.0 to 214.4	68.2	2.5	65.8
6	I-70 E	2.97	3.8 to 6.7	67.3	10.3	57.0
7	I-70 E	4.45	60.5 to 65.5	79.2	25.5	53.6
8	I-70 E	7.09	115.4 to 122.5	50.6	2.1	48.5
9	I-70 E	2.32	0.9 to 3.2	56.7	8.4	48.3
10	I-69 N	9.96	316.0 to 326.0	57.3	10.9	46.4
11	I-94 E	0.75	9.8 to 10.5	54.6	9.4	45.2
12	I-70 W	4.60	95.5 to 91.0	68.6	14.4	44.2
13	I-65 S	9.20	214.7 to 205.5	49.5	6.7	42.9
14	I-69 N	4.58	205.4 to 210.0	53.0	11.9	41.1
15	I-65 S	1.78	5.3 to 3.6	77.5	37.2	40.4
16	I-465 IL	1.30	13.9 to 15.2	59.7	22.3	37.4
17	I-65 S	14.28	229.6 to 215.3	64.3	27.8	36.4
18	I-94 E	0.28	9.5 to 9.8	40.6	4.5	36.0
19	I-65 S	0.42	2.2 to 1.7	85.9	50.4	35.5
20	I-65 S	0.44	1.7 to 1.3	111.6	77.2	34.3

Mobility Report Performance Measures

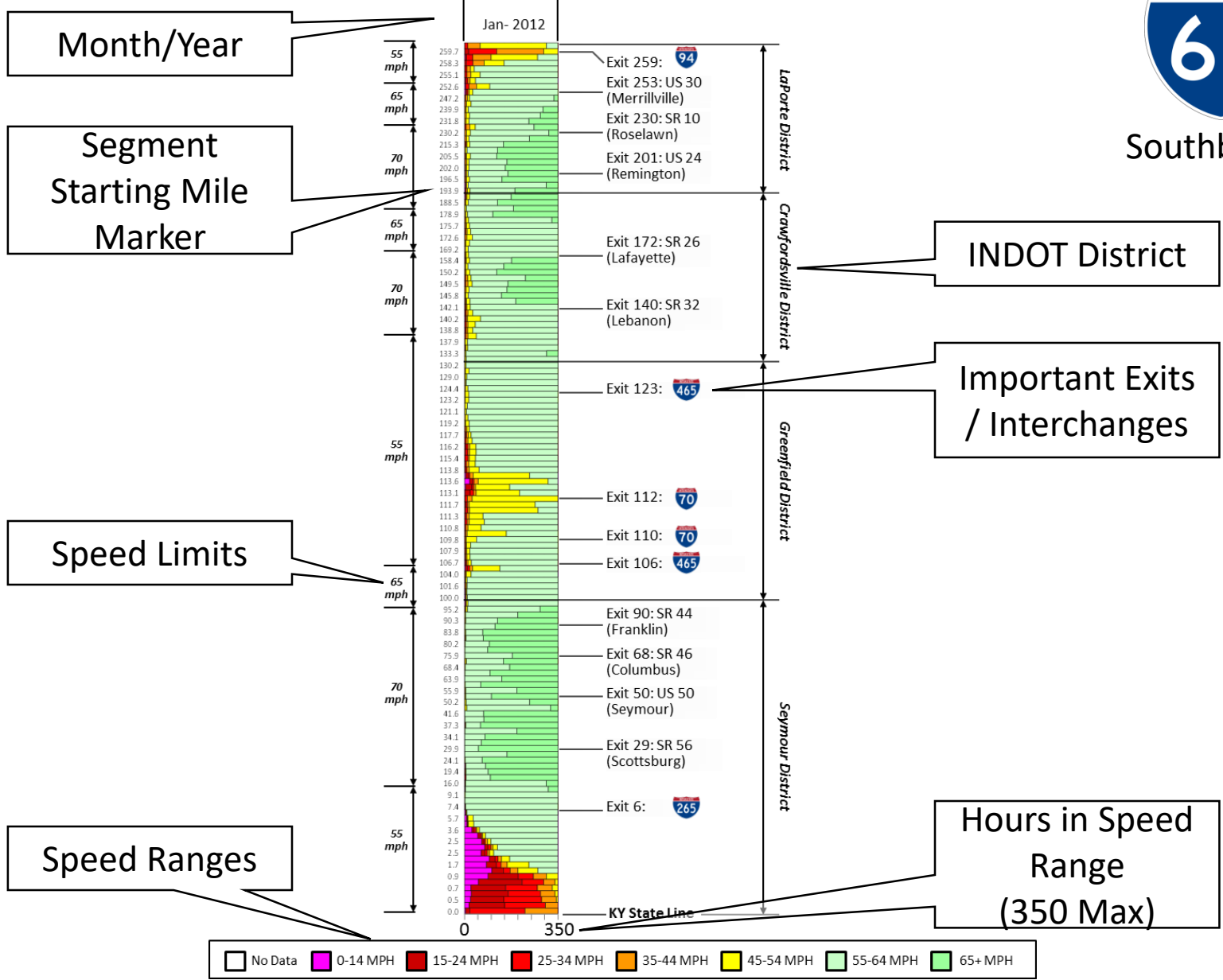


Mobility Report Performance Measures

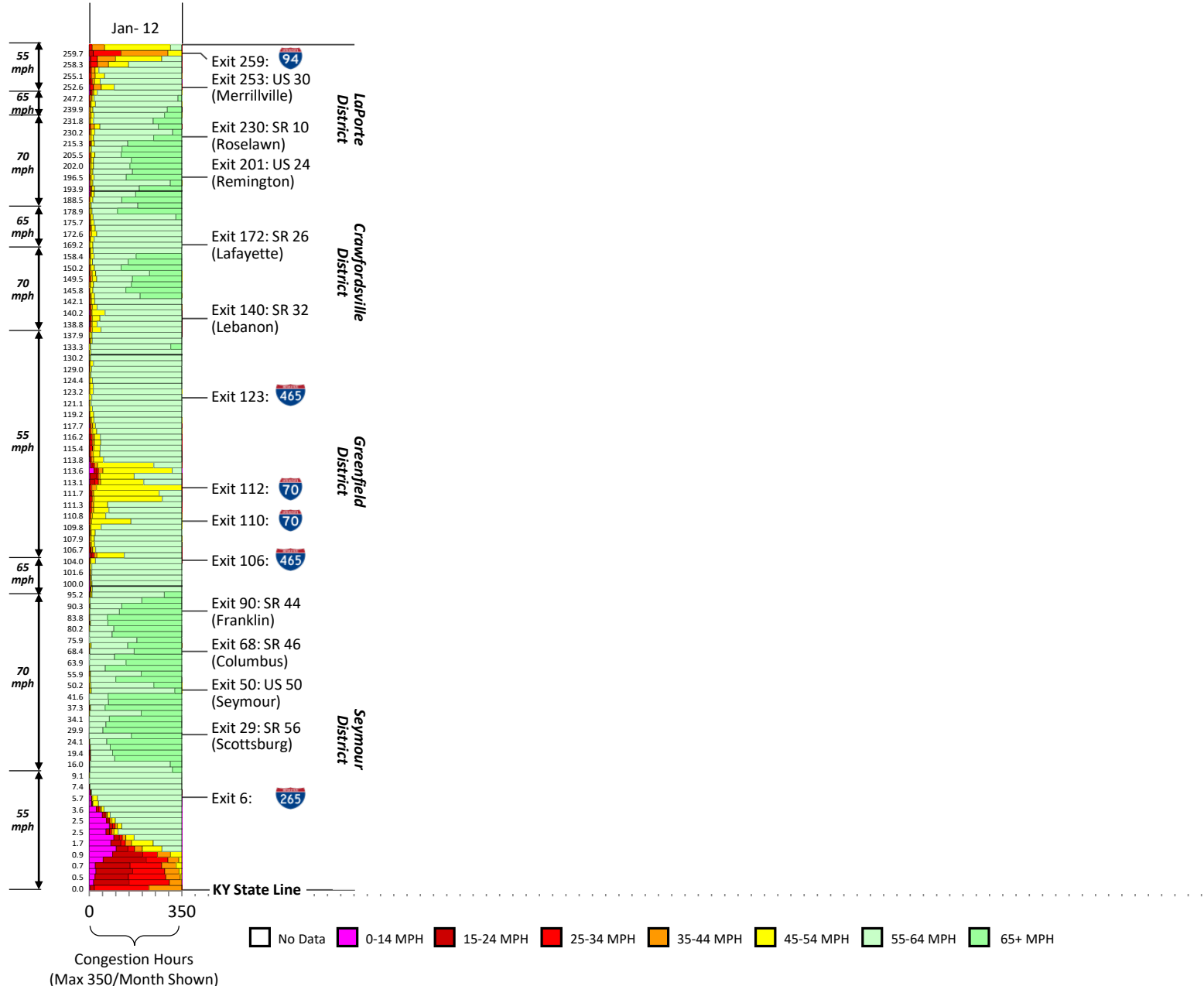
2012 Performance Measures: Speed Profile Diagrams



Southbound



Mobility Report Performance Measures



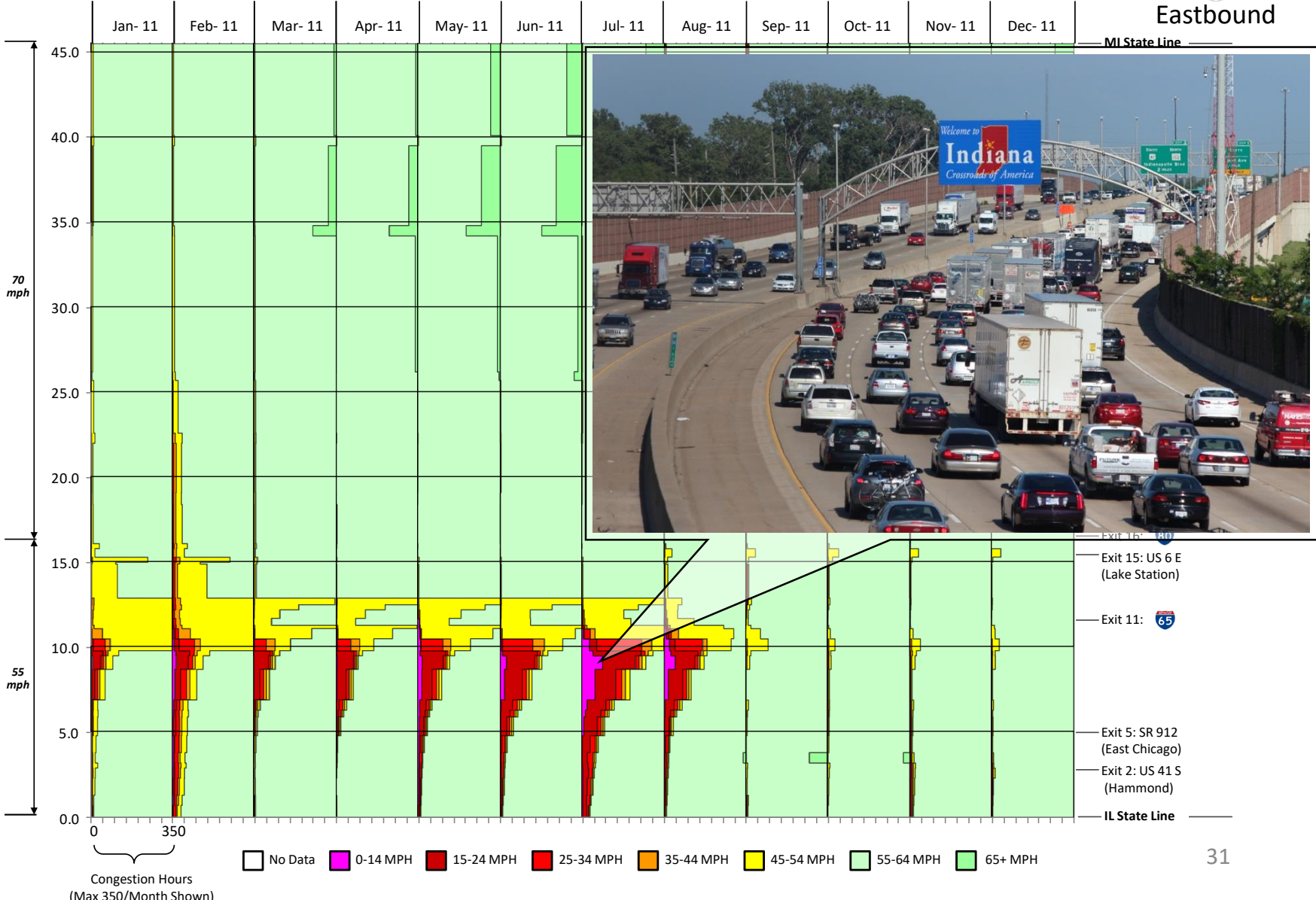
Mobility Report Performance Measures

2012 Performance Measures: Speed Profile Diagrams

2011



Eastbound



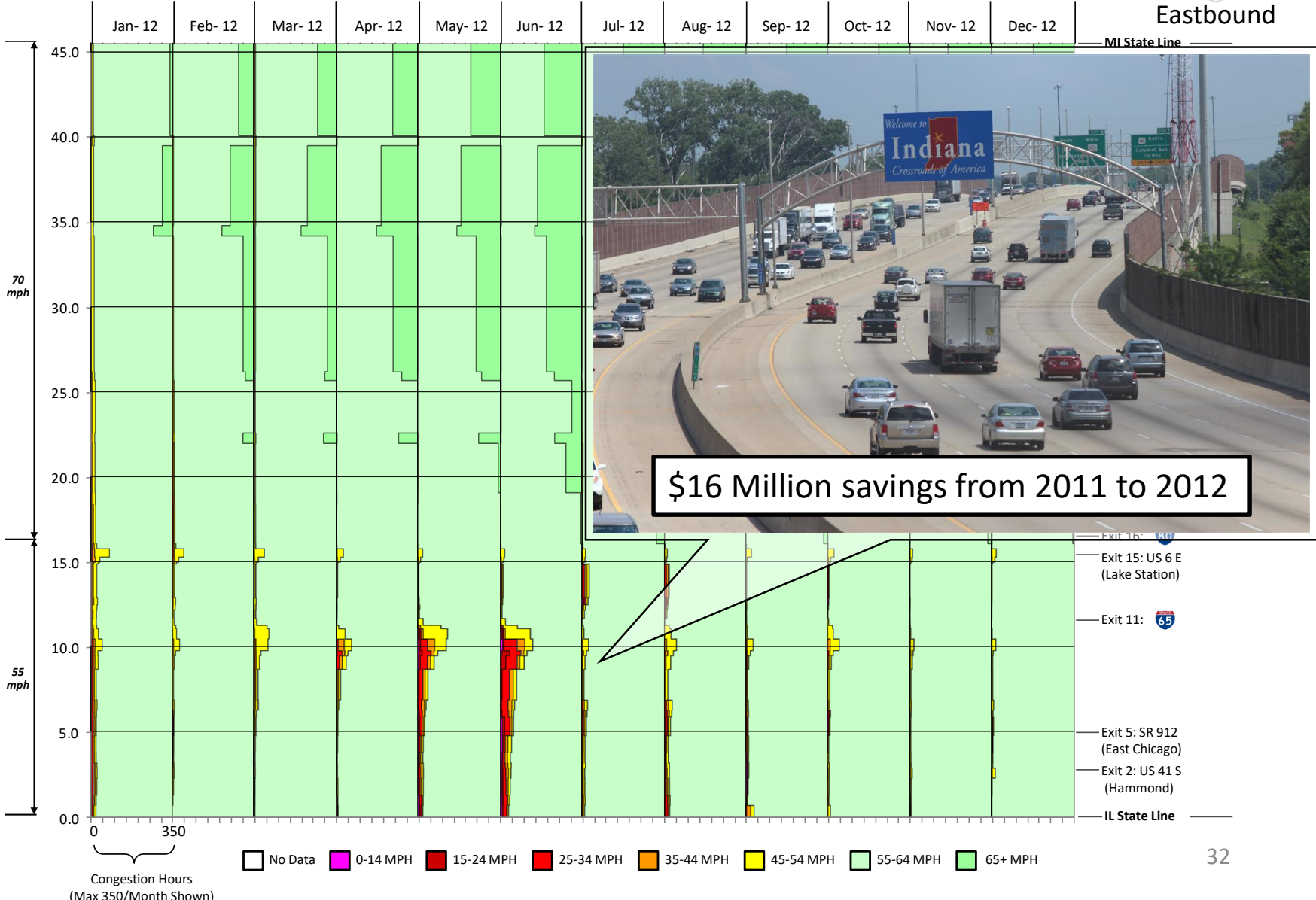
Mobility Report Performance Measures

2012 Performance Measures: Speed Profile Diagrams

2012



Eastbound



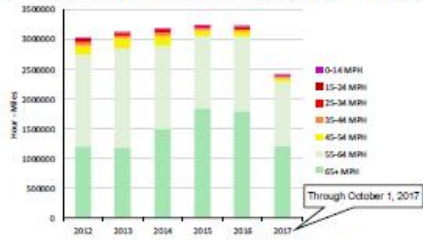


Traffic Mobility on I-75 in Michigan 2012-2017

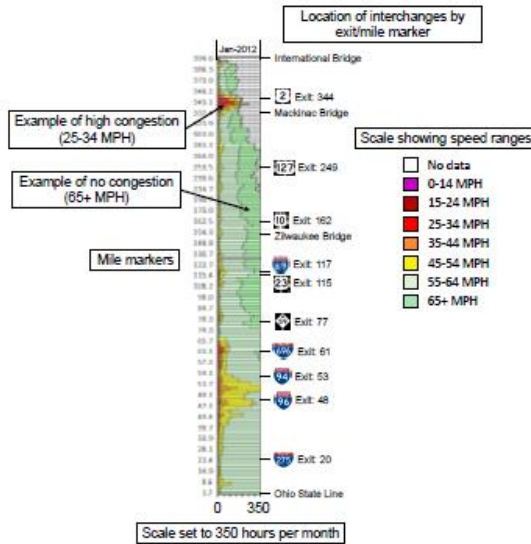
Jenna Kirsch, Student Research Assistant
Steve Remias, Assistant Professor



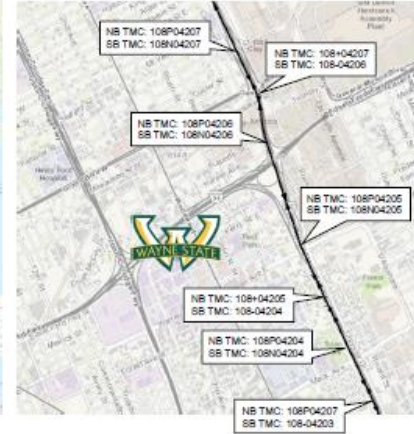
Hour - Miles per Speed Range (2012 - 2017)



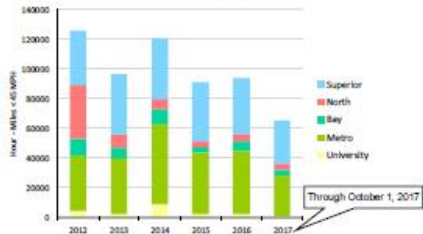
Speed Profile Performance Measure



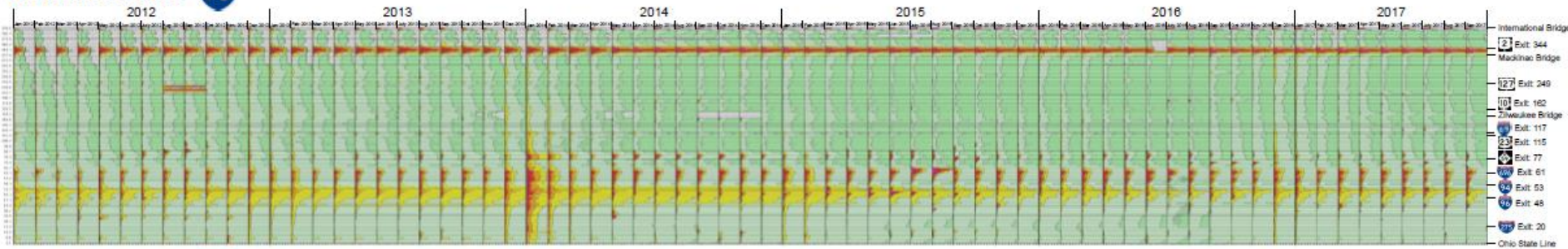
Traffic Message Channels (TMCs)



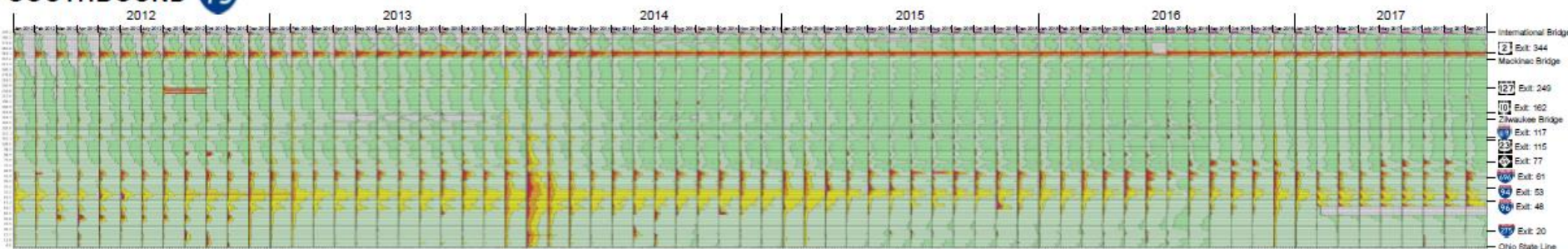
Hour - Miles < 45 MPH per MDOT Region (2012 - 2017)



NORTHBOUND I-75



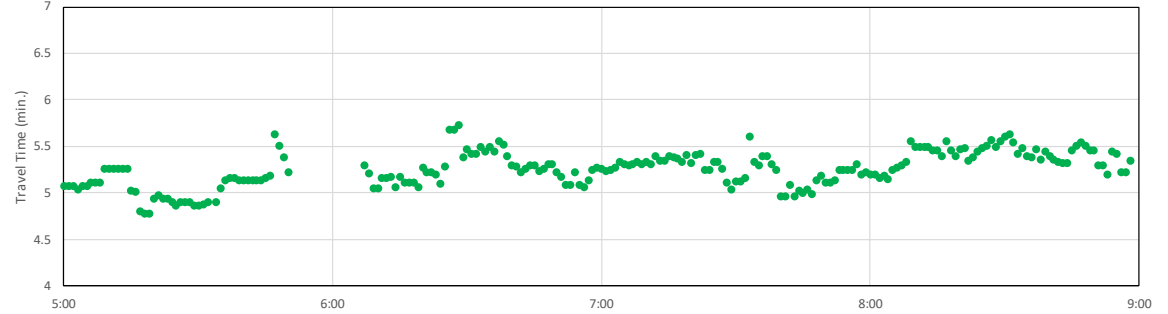
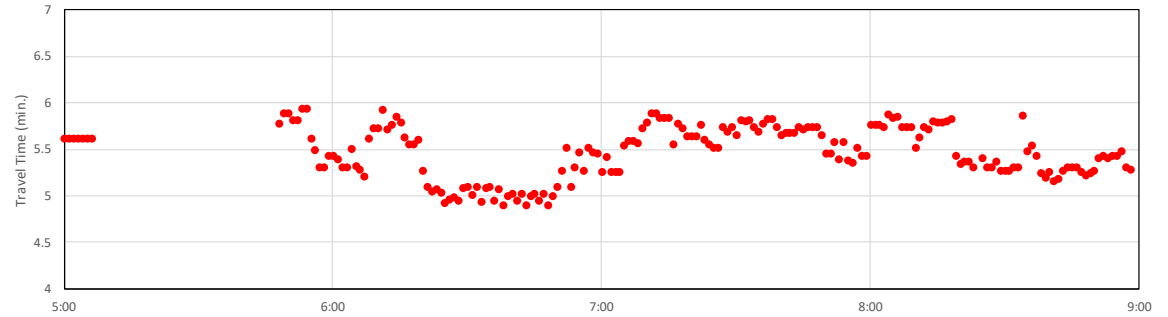
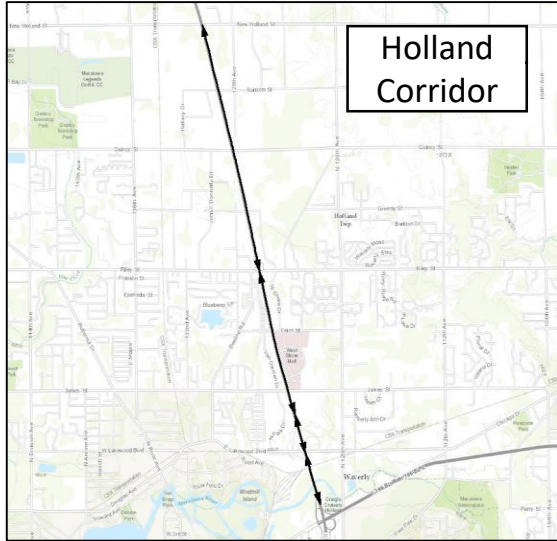
SOUTHBOUND I-75



Offset Recalibration

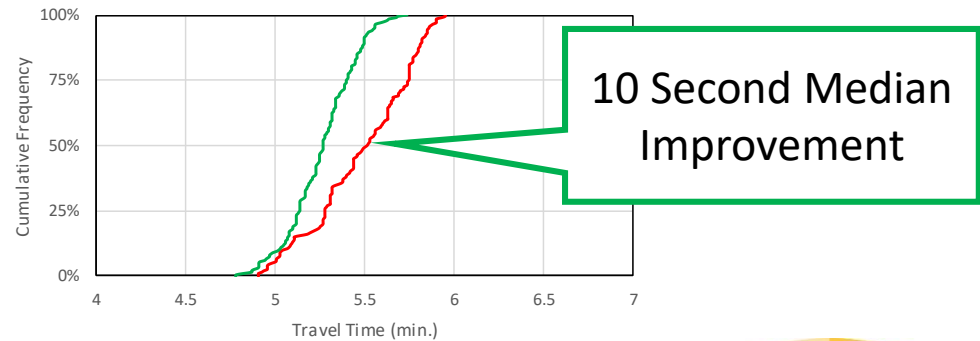
Probe Vehicle Travel Times

US-31 Northbound Corridor



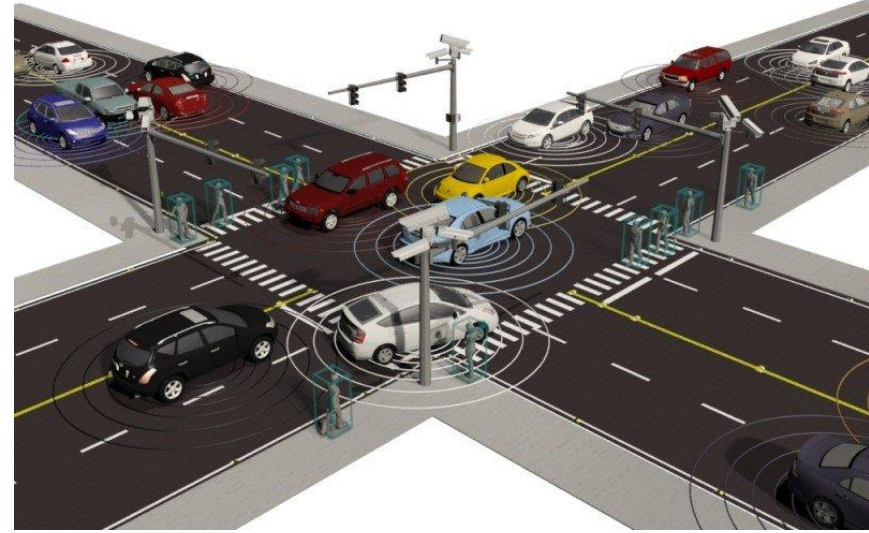
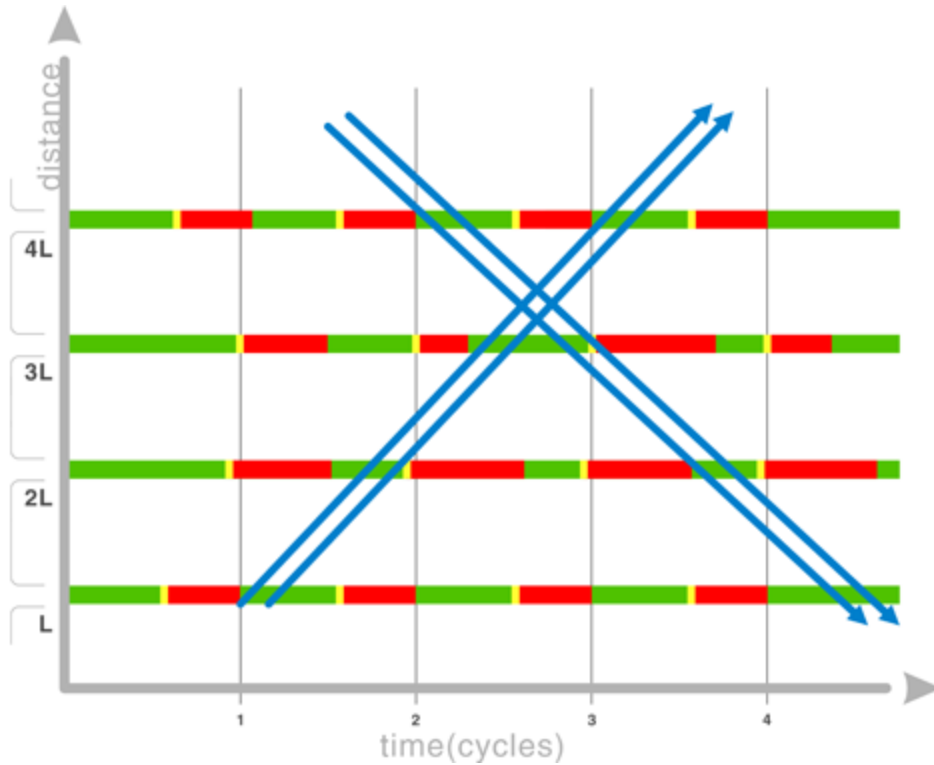
SEPTEMBER 2017						
S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

- █ Before Offset Retiming
- █ Day of Offset Retiming
- █ After Offset Retiming



Connected Vehicle Technology

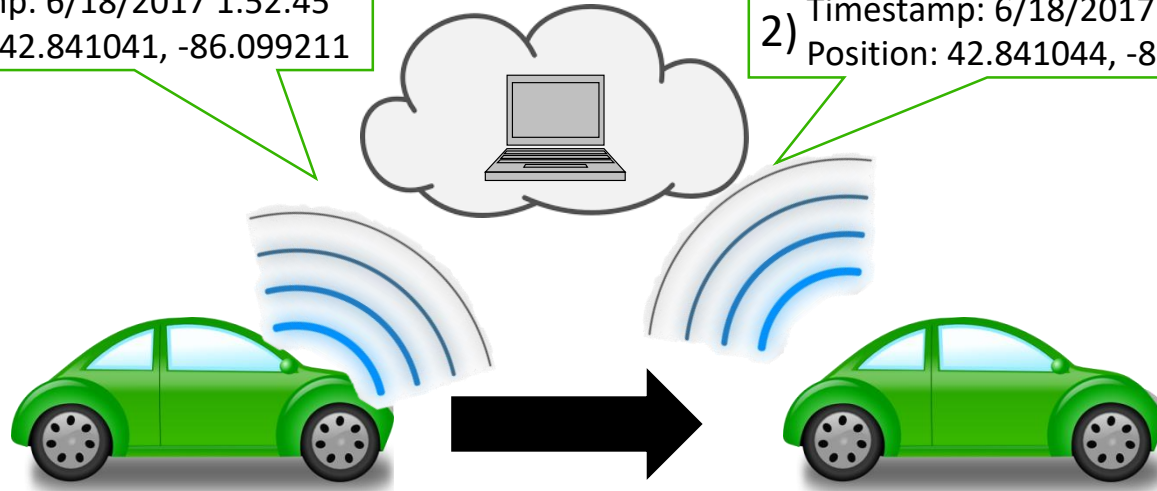
Old School vs. New School



Automated Vehicle Location (AVL) Data

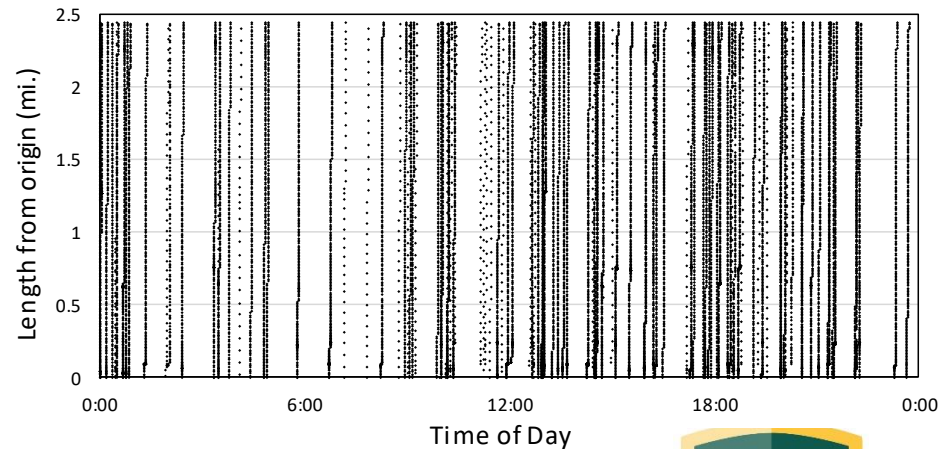
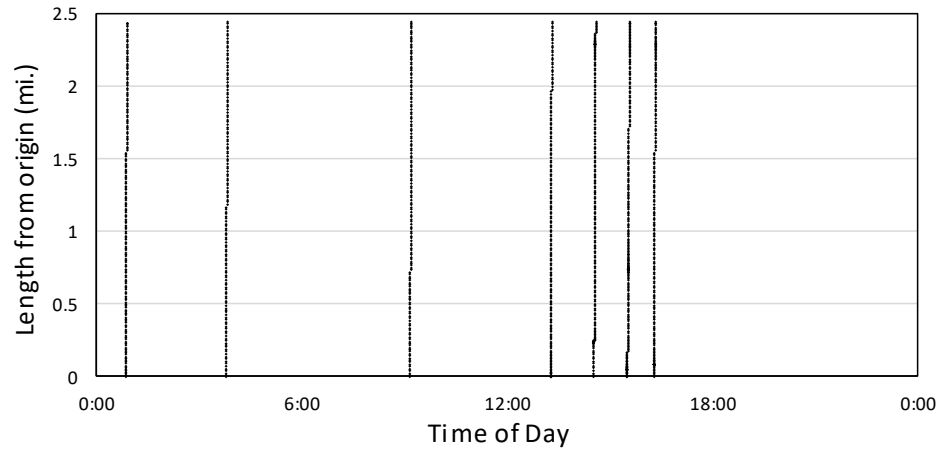
1) Timestamp: 6/18/2017 1:52:45
Position: 42.841041, -86.099211

2) Timestamp: 6/18/2017 1:53:00
Position: 42.841044, -86.099216



One Day (7/3/2017)

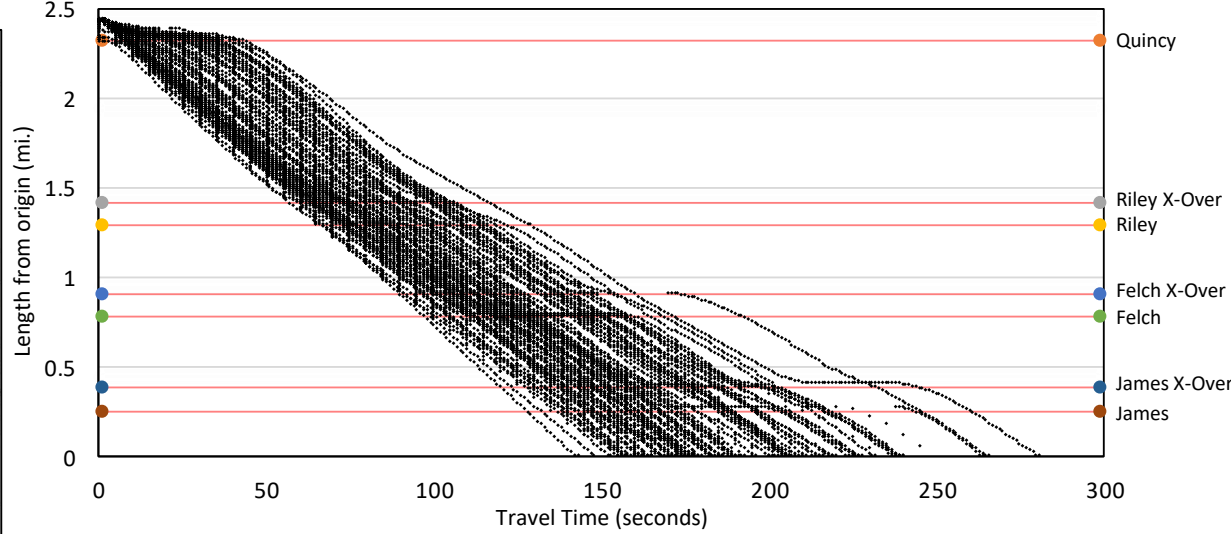
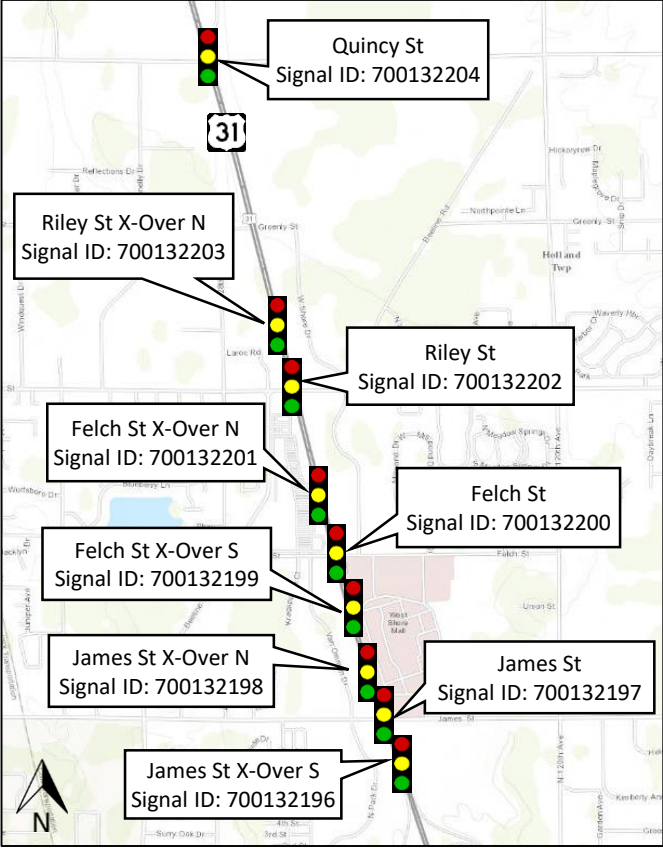
Two Weeks (7/1-14/2017)



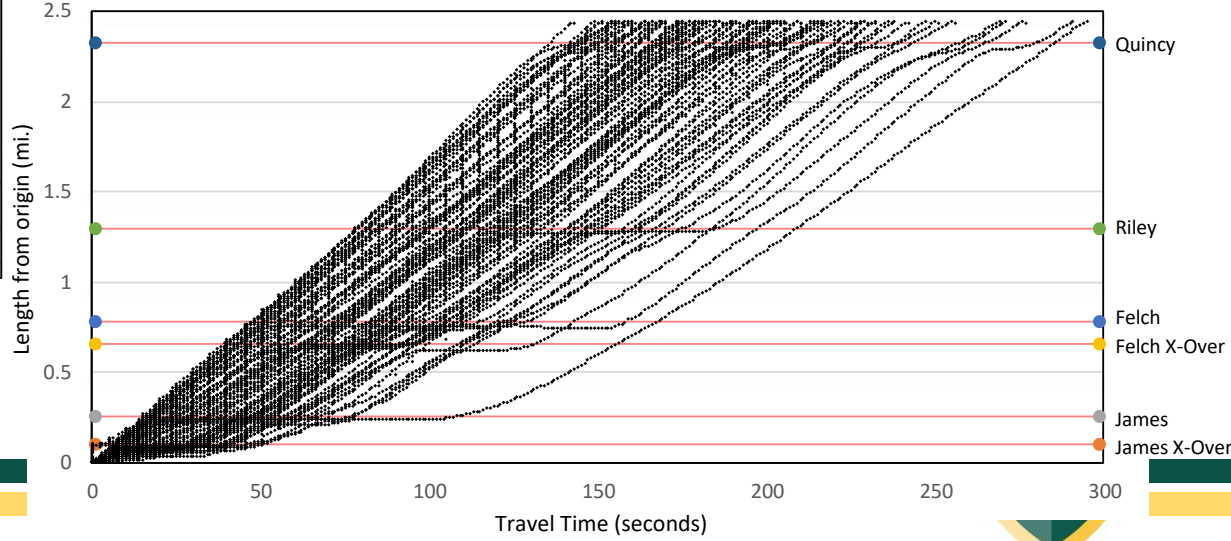
Computation Transport Science

Computer Science in the Transportation Field

Southbound



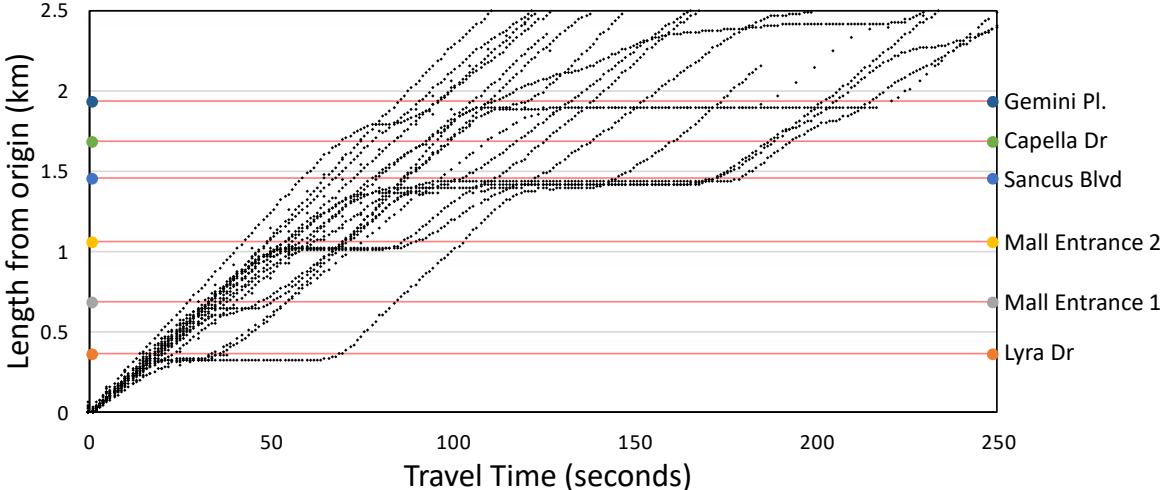
Northbound



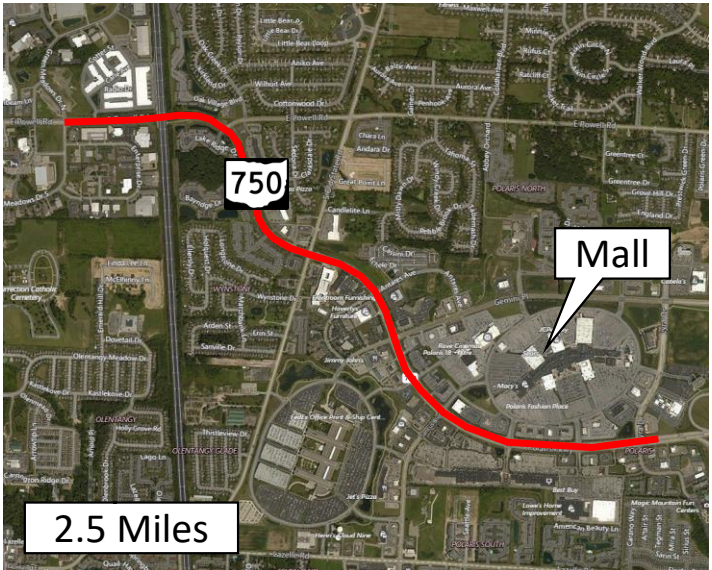
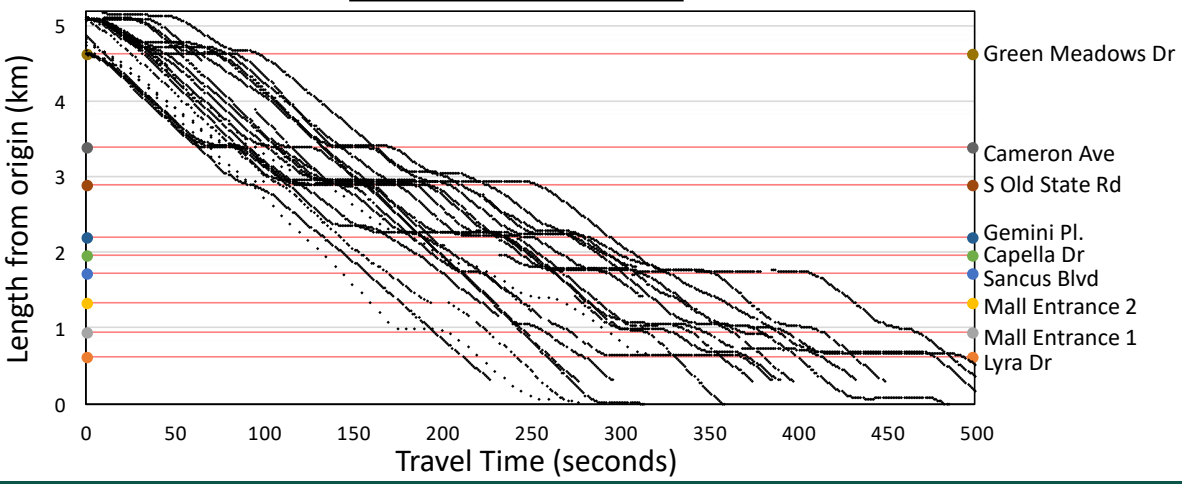
Scalability

Columbus, OH

WESTBOUND

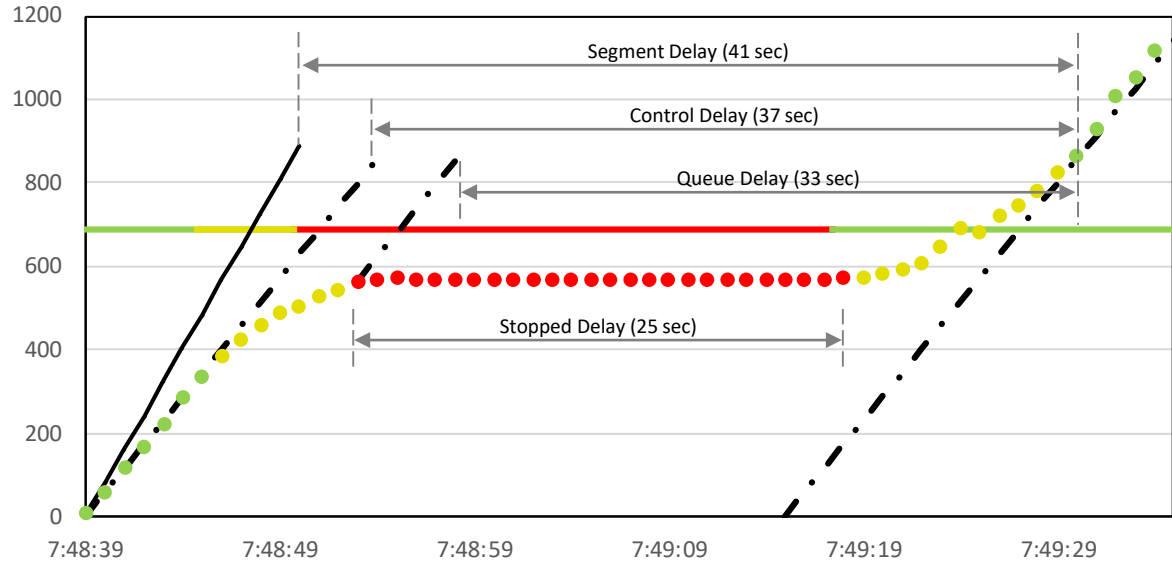
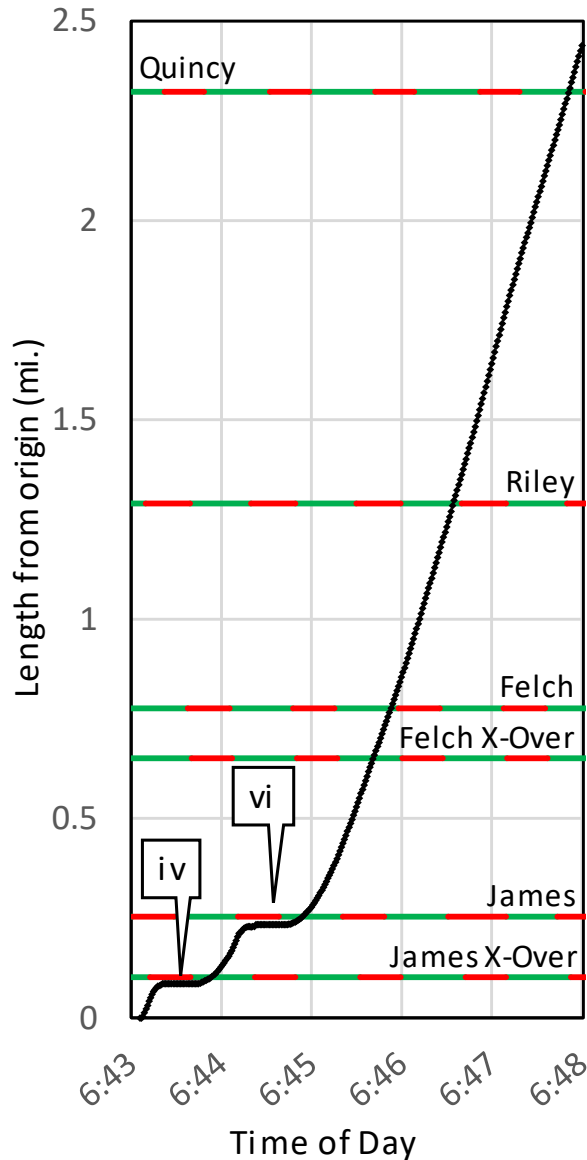


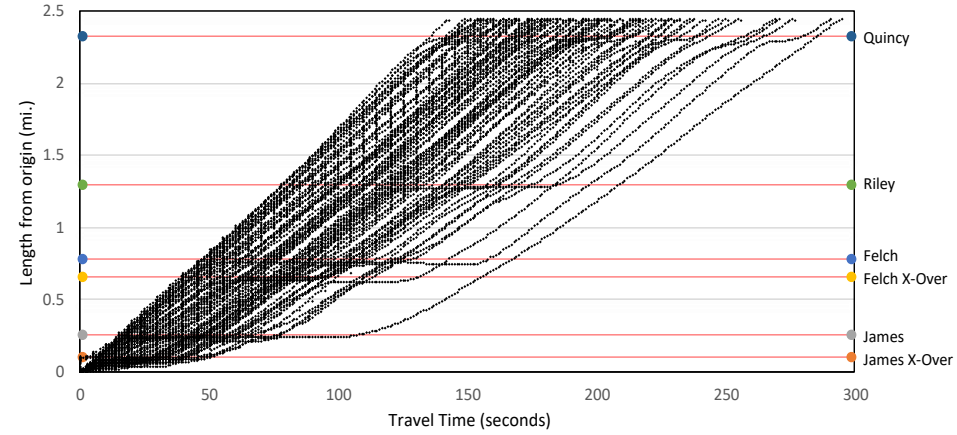
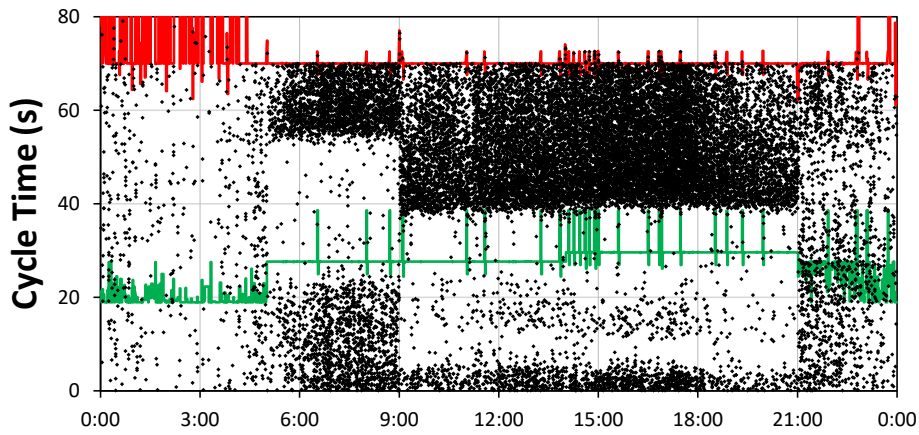
EASTBOUND



Data Fusion

Signal Performance Measures and AVL Data





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 Assistant Professor
 Civil and Environmental Engineering

