Traffic Signal Performance Measures Workshop

JOINT TRANSPORTATION RESEARCH PROGRAM
Discovery with Delivery
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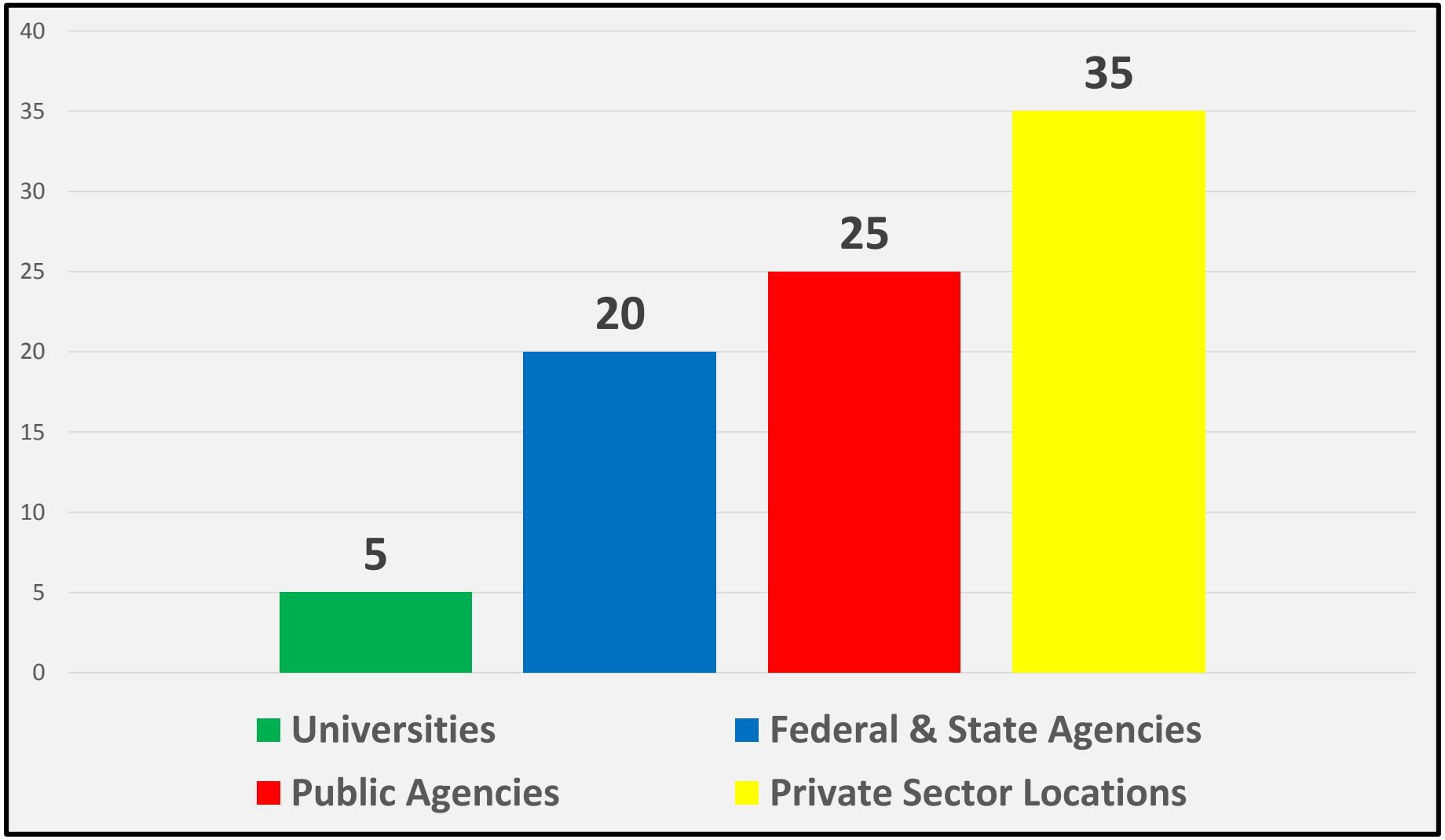
JTRP

PURDUE
UNIVERSITY

INDIANA DEPARTMENT OF TRANSPORTATION
INDOT

CALIFORNIA REPUBLIC
KANSAS
WISCONSIN
1848

169 Registered Participants Representing 85 Organizations



Messages

1. Web dissemination
2. Background/Context/Attribution
3. Performance Measure Pyramid
   - Communication
   - Detectors
   - Splits
   - Coordination
4. Longitudinal System Monitoring
5. Outcome Assessment Telling Our Story
6. Performance Measures will not reduce consulting, but I believe their services will evolve

AUTOMATED TRAFFIC SIGNAL PERFORMANCE MEASURES WORKSHOP

The Automated Traffic Signal Performance Measure (SPM) Workshop, held on January 26–27, 2016, in Salt Lake City, Utah, provided a forum to share best practices, agency progress, and configuring and troubleshooting tips, as well as to discuss the potential future of SPMs. Representatives from more than 70 organizations—including state and federal agencies, local agencies, universities, vendors, and consultants—attended. Presentations and posters can be accessed via the link below.

The SPM Workshop was sponsored by the National Operations Center of Excellence, the American Association of State Transportation Officials Initiative on SPMs, the Transportation Pooled Fund Program for Traffic Signal Systems Operations and Management led by the Indiana Department of Transportation and Purdue University, and the Utah Department of Transportation.

Browse the contents of Automated Traffic Signal Performance Measures Workshop:

Presentations and Posters

Workshop posters & related manuscripts available on e-Pubs.

Posters

RSS

2016

Tuesday, January 26th

Visualization and Assessment of Arterial Progression Quality Using High Resolution Signal Event Data and Measured Travel Time

Christopher Day, *Purdue University*
Ross Haseman, *Purdue University*
Hiromal Premachandra, *Purdue University*
Thomas Brennan, *Purdue University*
Jason Wasson, *Indiana Department of Transportation*
James Sturdevant, *Indiana Department of Transportation*
Darcy Bullock, *Purdue University*
12:00 AM

Reliability, Flexibility, and Environmental Impact of Alternative Arterial Offset Optimization Objective Functions

Christopher Day, *Purdue University*
Thomas Brennan, *Purdue University*
Alexander Hainen, *Purdue University*
Stephen Remias, *Purdue University*
Hiromal Premachandra, *Purdue University*
James Sturdevant, *Indiana Department of Transportation*
Greg Richards, *Indiana Department of Transportation*
Jason Wasson, *Indiana Department of Transportation*
Darcy Bullock, *Purdue University*
12:00 AM

Sign this form to publish your workshop presentation.

Agreement for deposit of ATSPMW Presentations to Purdue e-Pubs

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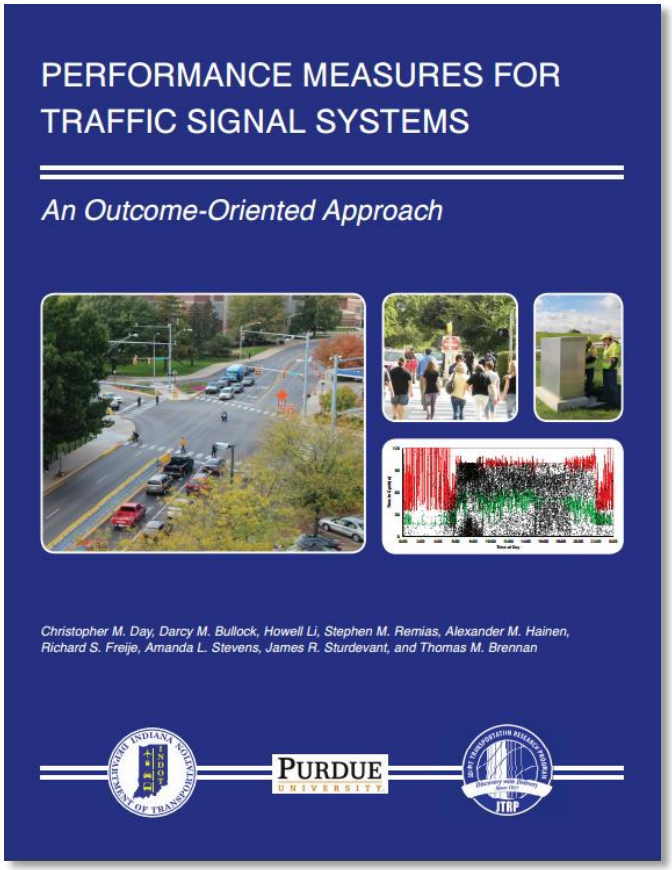
Signature *Date*

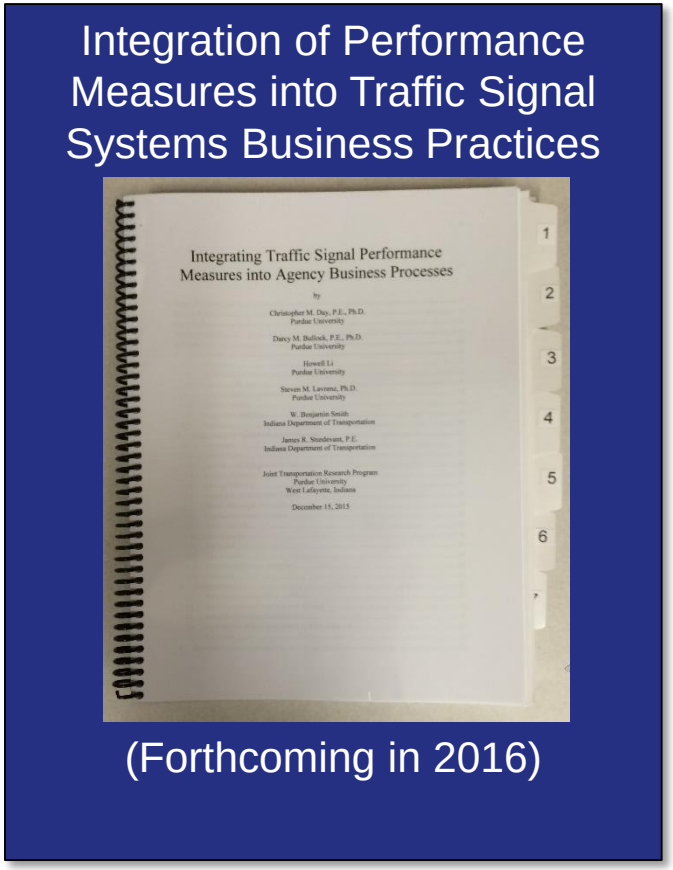
Pooled Fund Study Products (FHWA, Purdue and Agency Partners)



"Volume 1"

Defining Performance Measures…

Download at: **tinyurl.com/signalmoe**

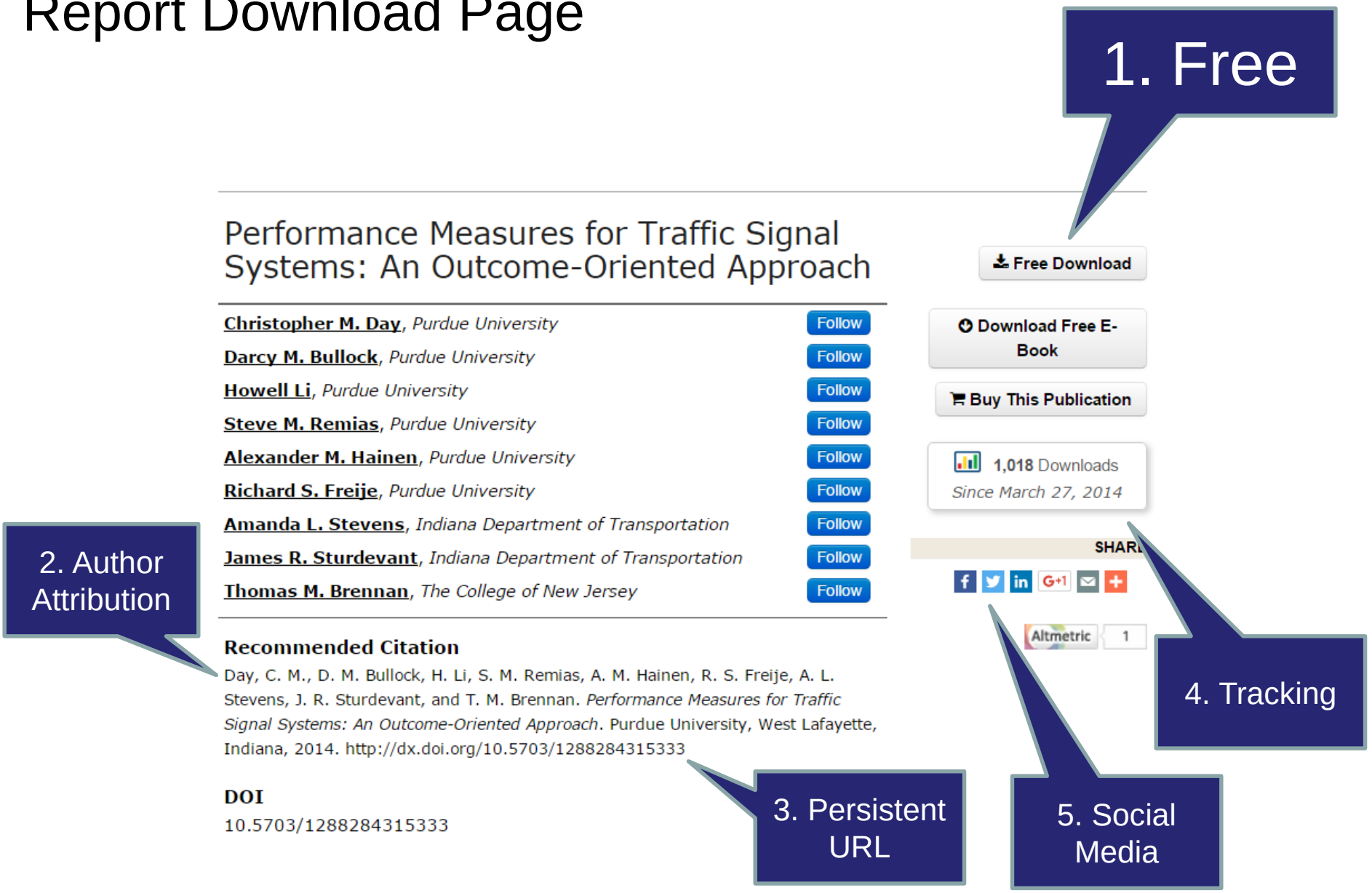


"Volume 2"

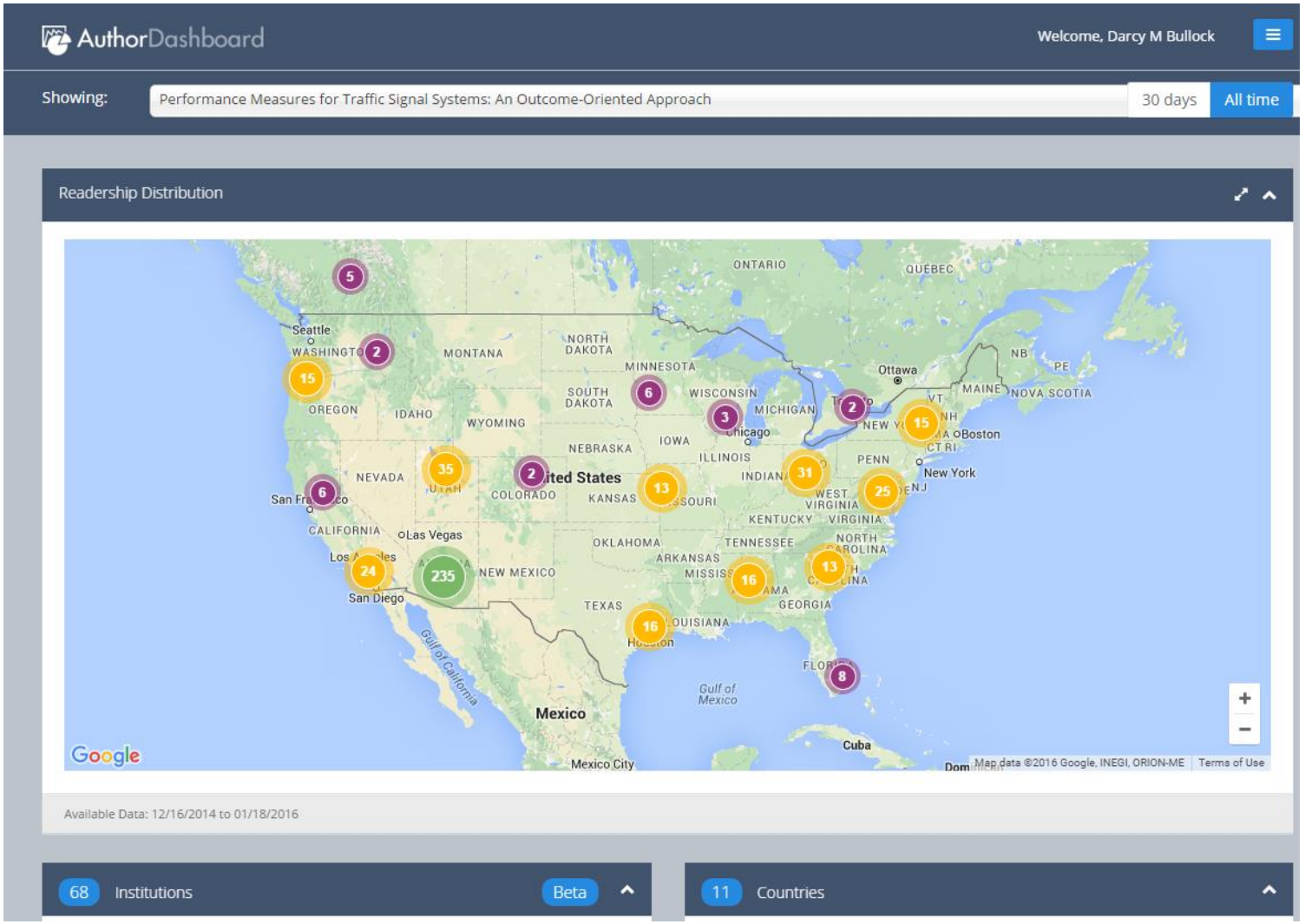
Business Practices, Use Cases, and Implementation…

Estimated to publish in March 2016

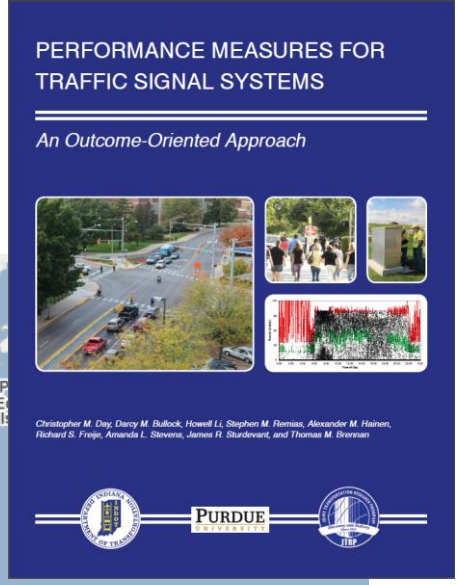
Report Download Page



Quarterly Report on Downloads



Pooled Fund Partners

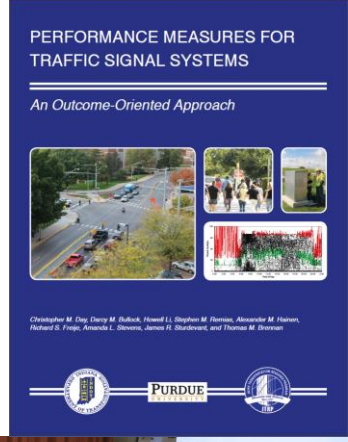


Indiana, California, Utah, Texas, Minnesota, Wisconsin, Chicago DOT, Mississippi, Georgia, New Hampshire

POOLED FUND STUDY

INDIANAPOLIS

NOVEMBER 12, 2014



May 2015 ATL Workshop

October 2006 State of the practice

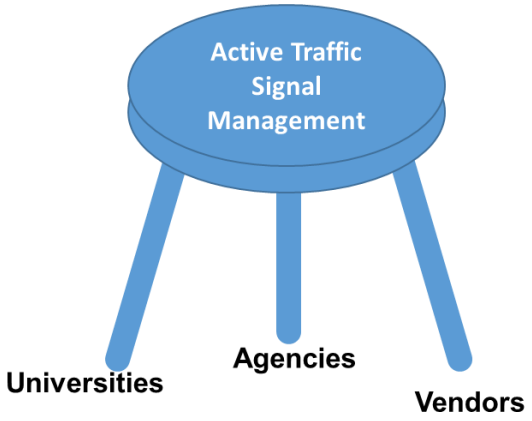
"If one wants to be outstanding in their field, one must first spend some time standing in the field" *Bill Kloose*


2012


2013

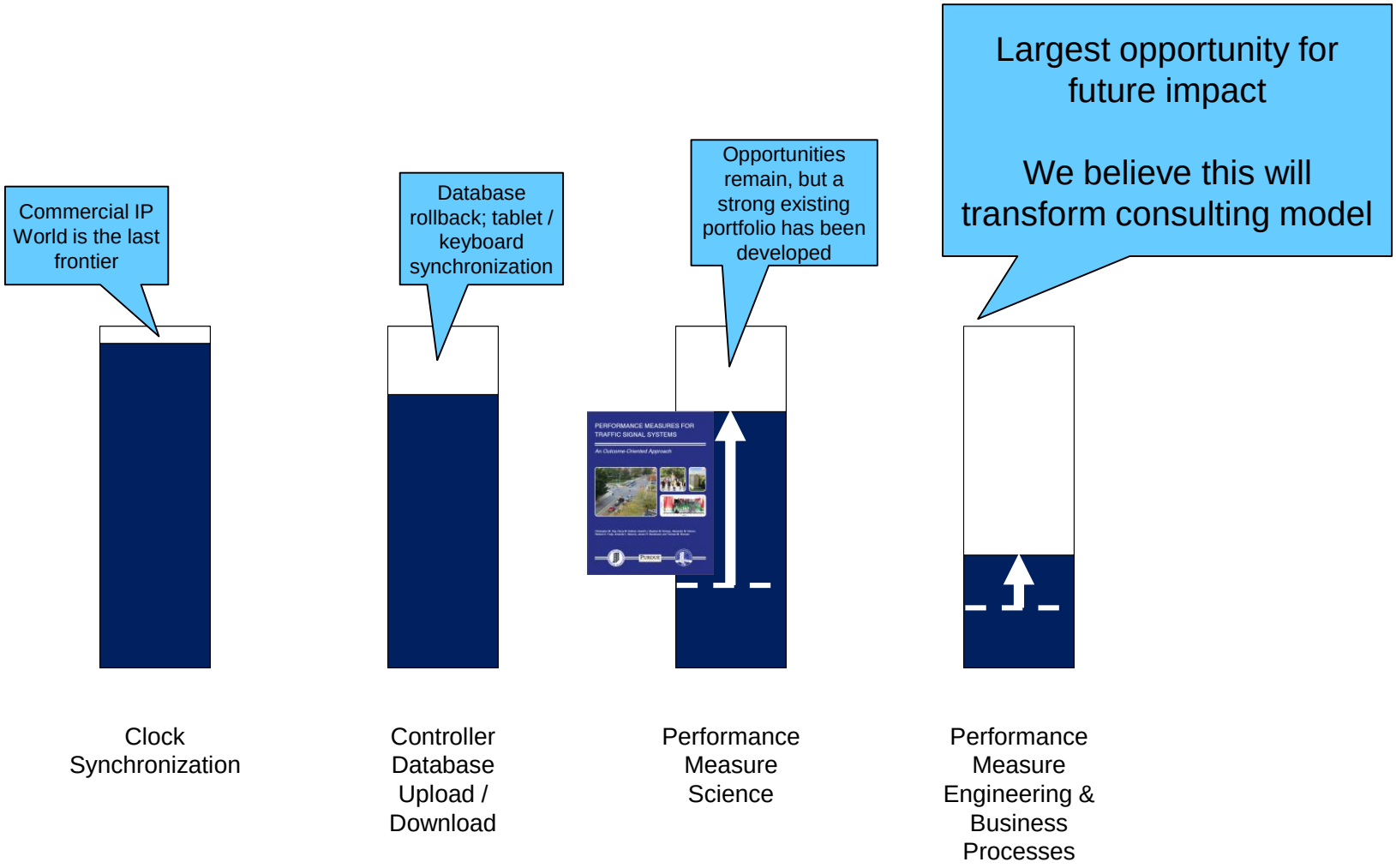

2013

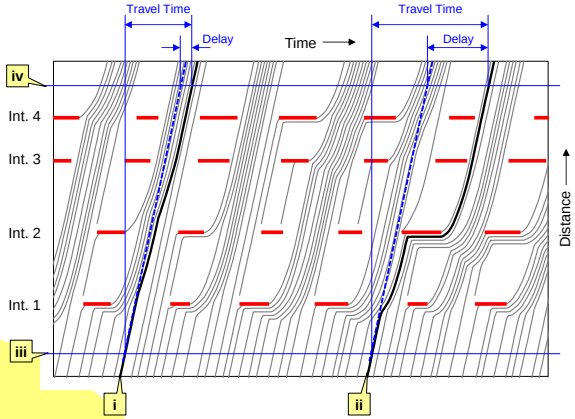
Themes



1. Research Framework Perspective & Collaborative Activities
2. Pyramid Perspective on Signal System Priorities
3. High resolution Data is critical for identifying operational intervention strategies
4. Probe Data is critical for communicating outcome assessment to Decision Makers
5. We believe the consulting model will change in the next three years to rely less on synchro and more on hi-resolution data and probe data

State of Signal Performance Measures Research





High Resolution Controller Data

Probe Data

Opportunities to Better Leverage Existing Infrastructure

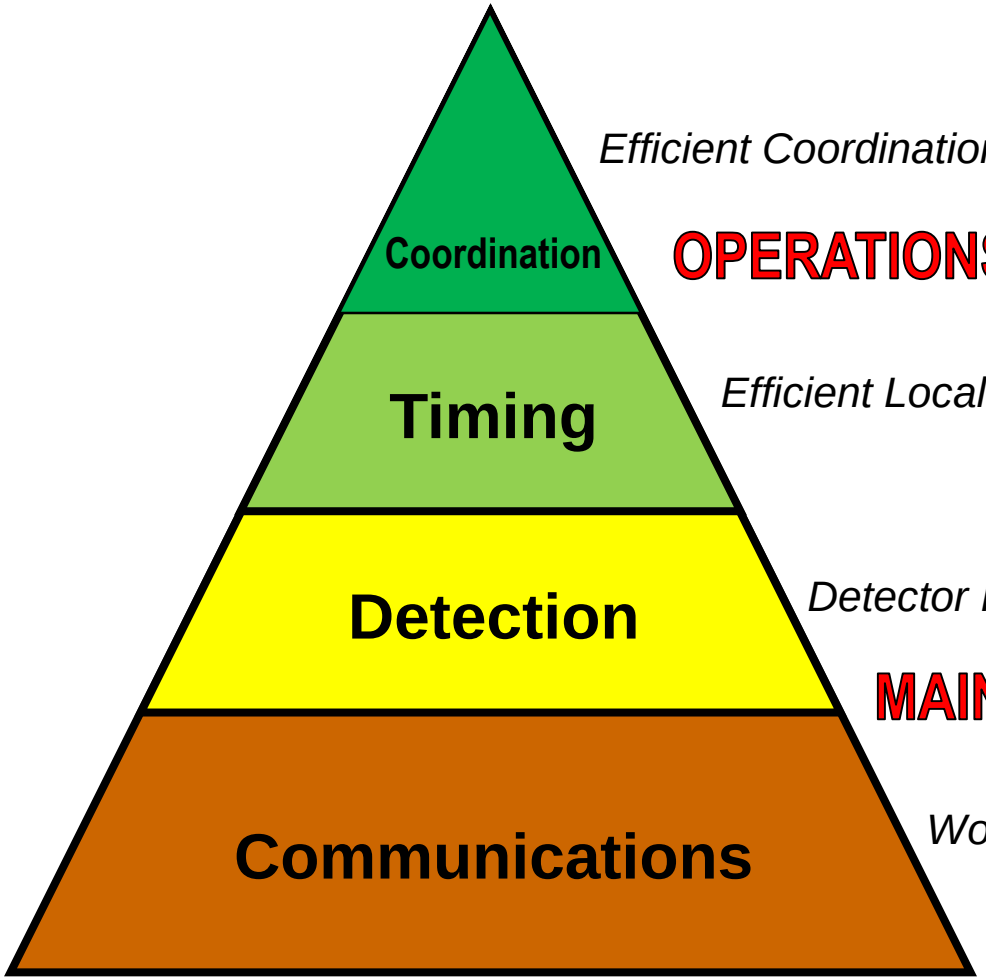
Opportunities to Push the State of the Possible

What gets measured gets done,
what gets measured and fed back gets done well,
what gets rewarded gets repeated.
– John E. Jones

Enormous opportunities to fuse/validate traffic signal data with probe data sources

MAP 21

Hi Resolution Data is Critical for Identifying Levers



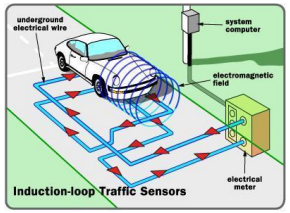
Efficient Coordination

OPERATIONS

Efficient Local Control

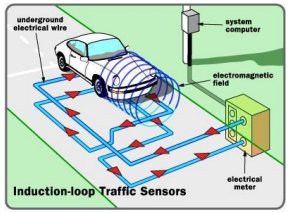
Detector Health

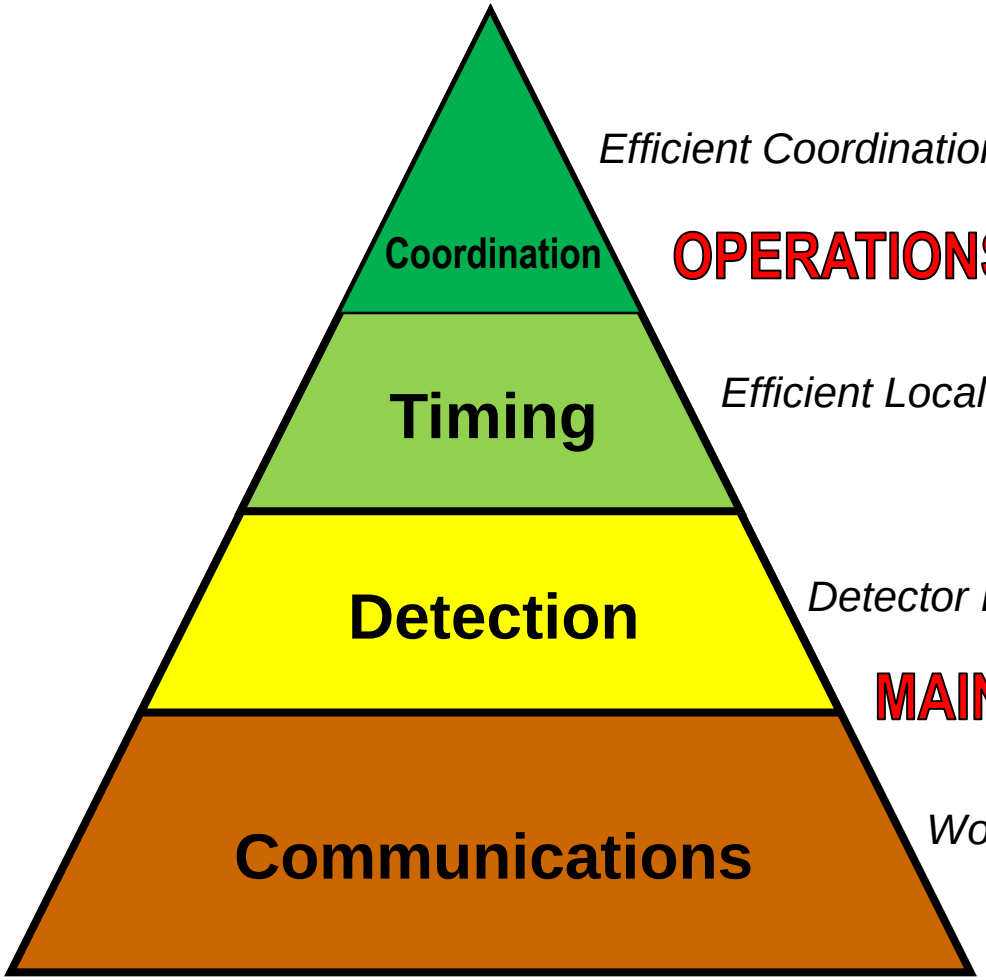
MAINTENANCE



Working Communications

Probe Data is integral for Outcome Assessment





Efficient Coordination

OPERATIONS

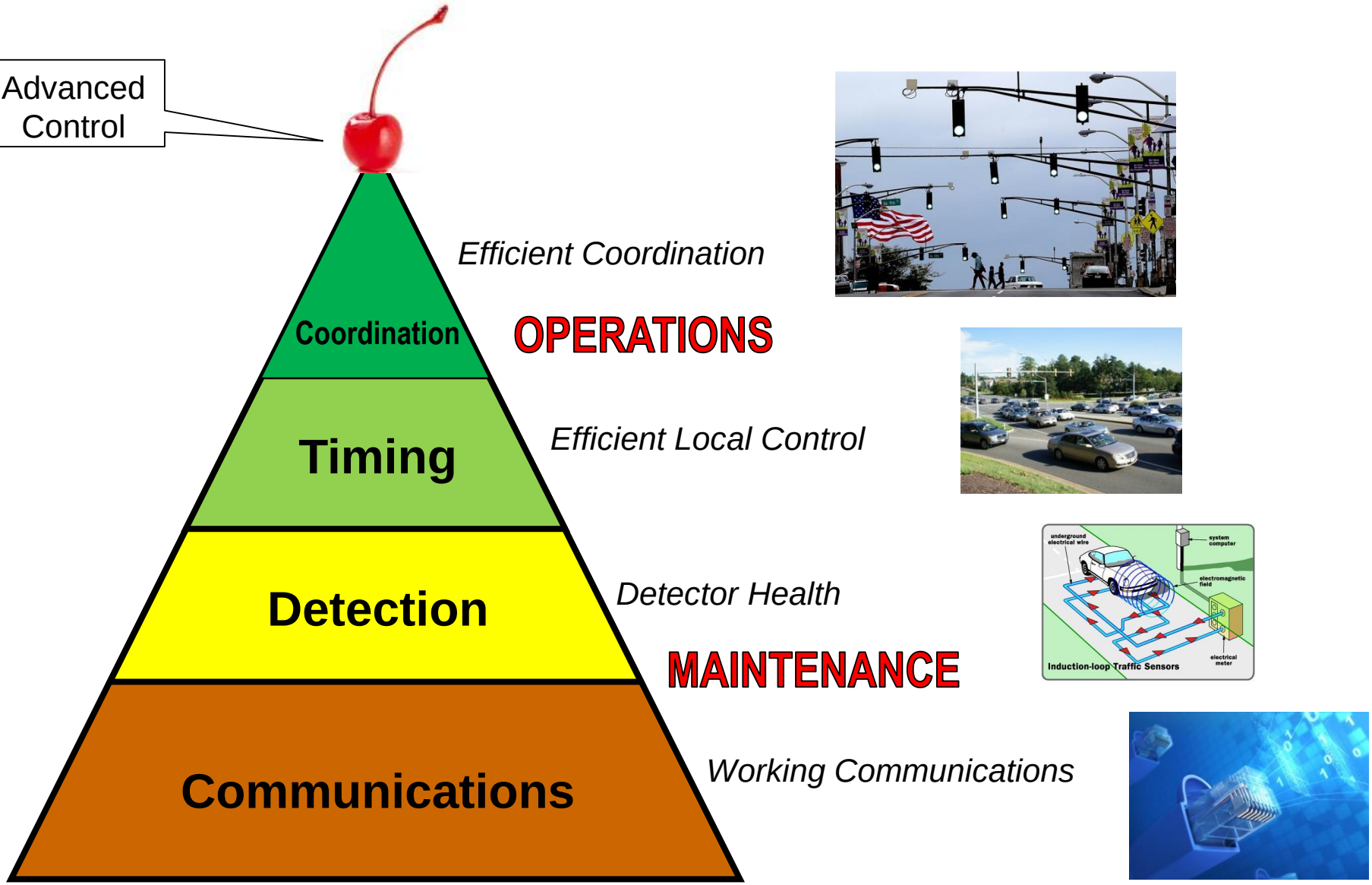
Efficient Local Control

Detector Health

MAINTENANCE

Working Communications

Advanced Control



Efficient Coordination

OPERATIONS

Efficient Local Control

Detector Health

MAINTENANCE

Working Communications

Advanced Control

Jims Slide

Coordination

Timing

Communication

Detection

Efficient Coordination

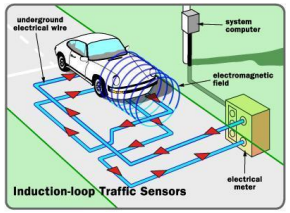
OPERATIONS

Efficient Local Control

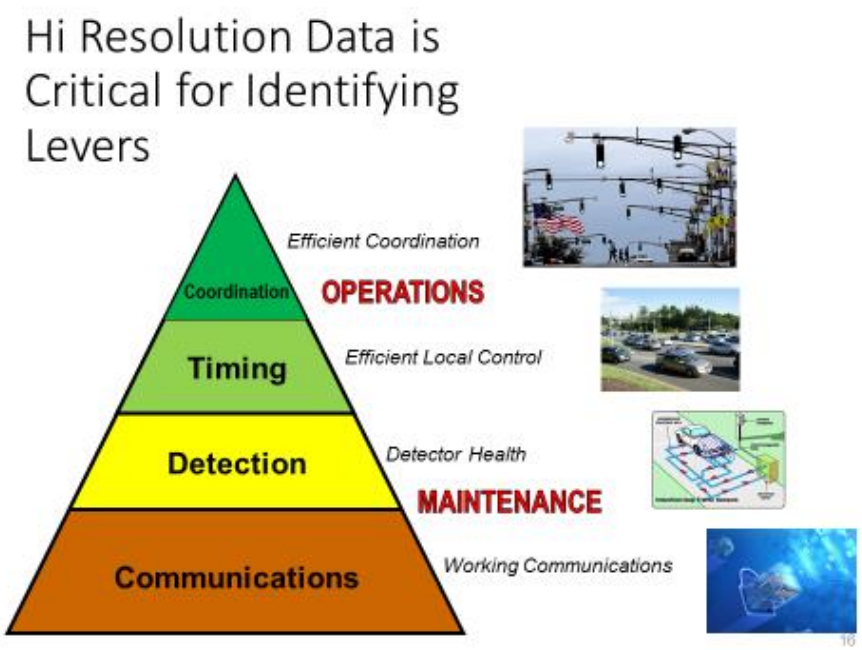
Detector Health

MAINTENANCE

Working Communications



Critical Performance Measures for Managing Signals

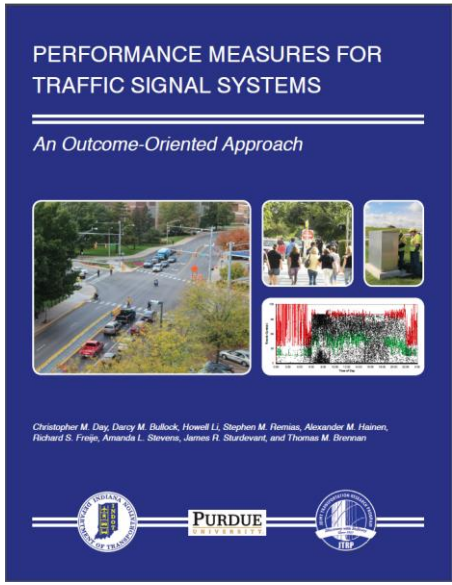


1. Is my communication working?
2. Are my detectors working?
3. Do I have adequate green time on each phase?
4. Do I have most of my vehicles arriving on green?

Write this Down if you agree!

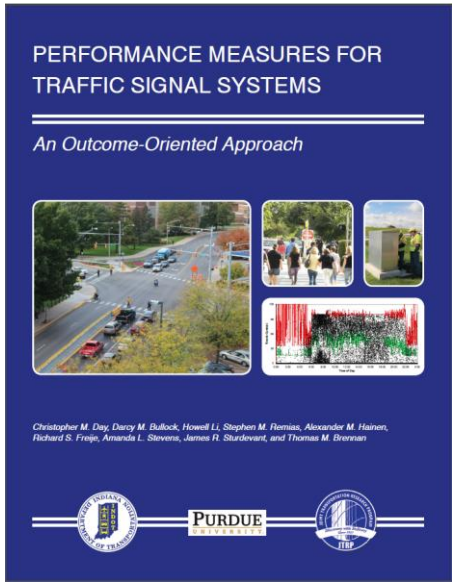
Portfolio of Performance Measures (p. 1)

MOE	Usage	Documented in Monograph	Journal Papers (DOI)
Cycle Length	Verify consistent controller programming along corridor, and quickly evaluate performance of fully-actuated signals	✓	10.3141/2128-05
Green Time and Capacity	Verify controller behavior	✓	10.3141/2035-11
Count and Volume	Characterize vehicle demand by movement	✓	10.3141/2035-11
Volume-to-Capacity Ratio	Evaluate utilization of provided capacity	✓	10.3141/2035-11
Degree of Intersection Saturation	Evaluate overall intersection utilization	✓	10.3141/2128-05
Percent on Green, Arrival Type	Evaluate progression performance	✓	10.3141/2035-11
Purdue Coordination Diagram	Visualize progression performance over a variety of time-scales	✓	10.3141/2192-04 10.3141/2259-06
Platoon / Flow Profile	Visualize progression performance for a given time period where a consistent cycle length occurs	✓	10.3141/2259-02
Estimated Queue Length	Estimate lengths of queues at intersections	✓	10.1016/j.trc.2009.02.003
Oversaturation Severity Index	Evaluate spatial and temporal characteristics of oversaturation in the street network		10.1016/j.trc.2010.01.003
Input-Output Delay	Estimate delay experienced by vehicles on movements where advance detection exists	✓	10.3141/2035-08.
Maximum Vehicle Delay	Estimate delay experienced by vehicles on movements where stop bar detection exists		TRB Paper # 15-0385
Estimated Vehicle HCM Delay	Estimate delay experienced by vehicles based on HCM methodology		10.3141/2259-03

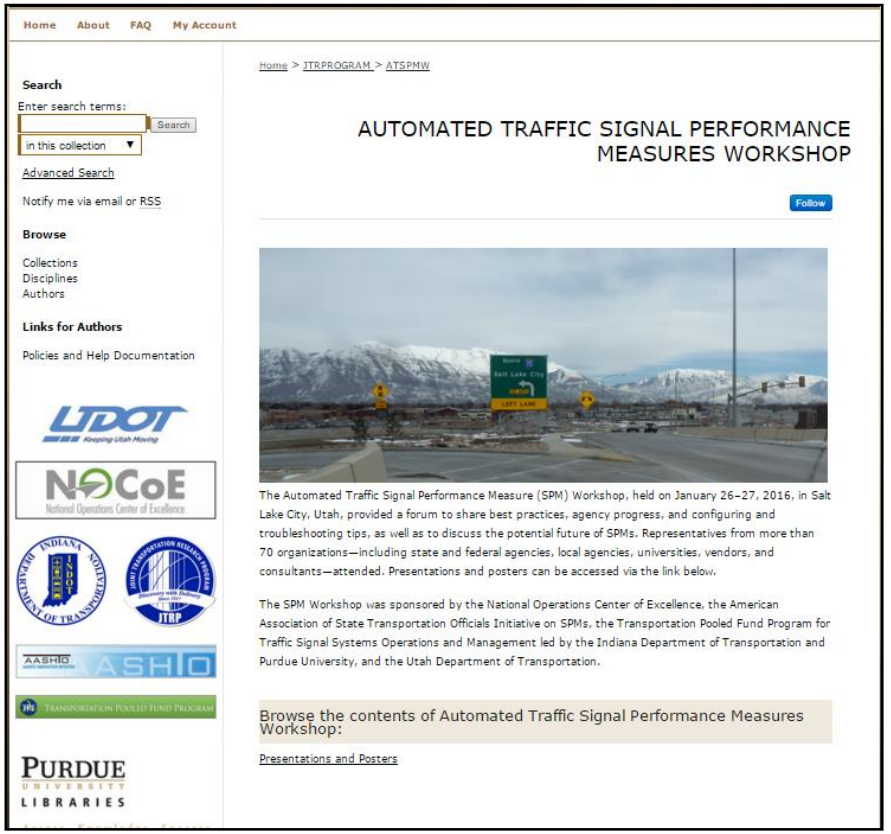


Portfolio of Performance Measures (p. 2)

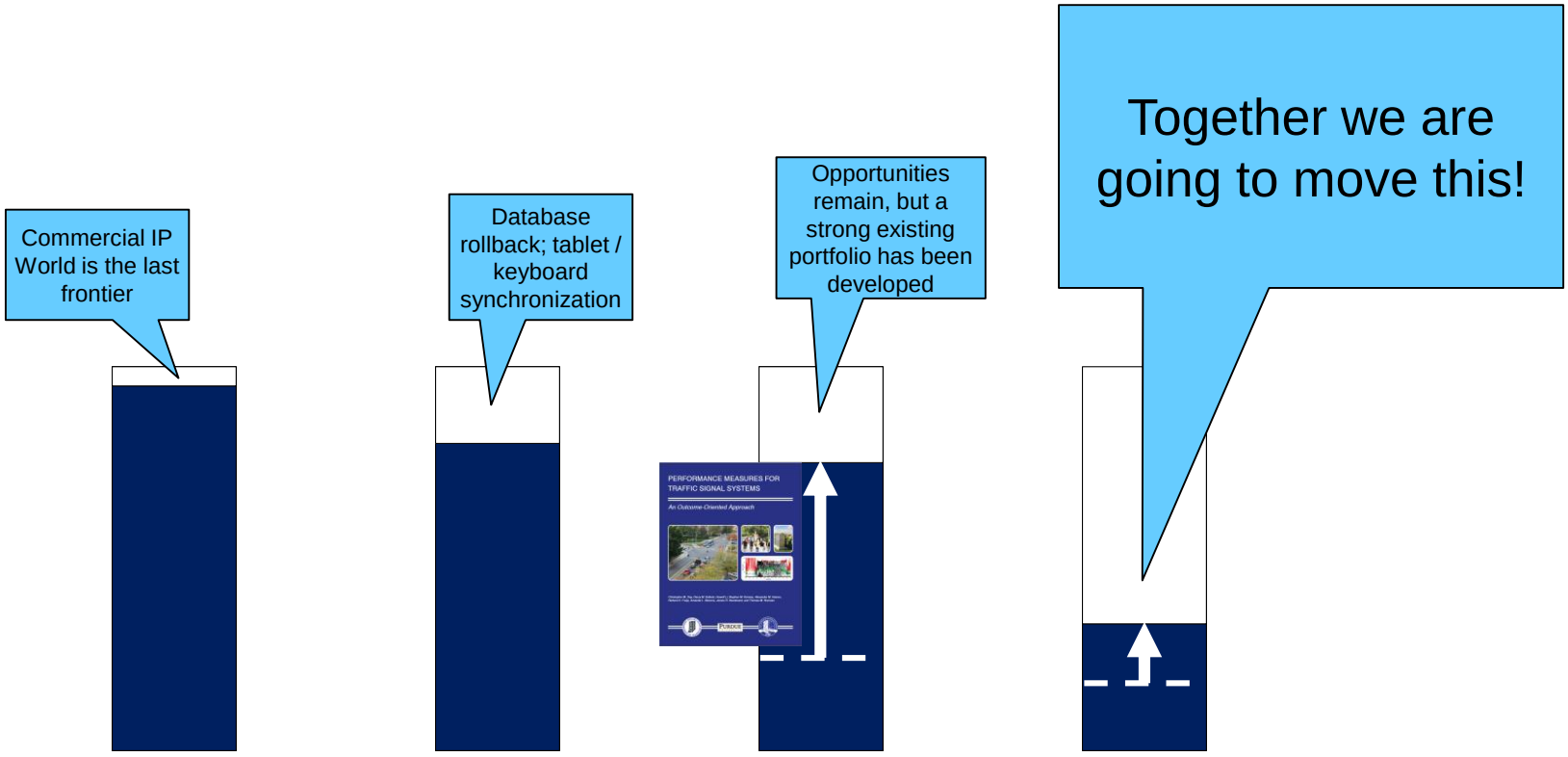
MOE	Usage	Documented in Monograph	Journal Papers (DOI)
Phase Termination Diagram	Visualize utilization of actuated phases	✓	10.3141/2355-03
Green Occupancy Ratio and Red Occupancy Ratio (ROR/GOR)	Estimate occurrence split failures where stop bar detection exists	✓	10.3141/2439-03
Platoon Characteristics	Estimate Robertson model parameters of vehicle platoons	✓	10.3141/2311-02
Coordination Optimization Potential	Estimate potential gains from adjusting signal timing for progression		(Unpublished)
Pedestrian Actuation Rate	Estimate utilization of intersection by pedestrians	✓	TRB Paper # 11-0220
Pedestrian Actuation to Service Time	Estimate delay experienced by pedestrians	✓	10.3141/2080-05
Estimated Pedestrian HCM delay	Estimate delay experienced by pedestrians based on HCM methodology		10.3141/2080-05
Pedestrian Conflicting Volume	Help determine effectiveness of pedestrian treatments	✓	10.3141/2080-05
Preempt Duration	Estimate amount of time that intersection is running limited service during preemption	✓	10.3141/2128-03
Preemption Event Diagram	Validate preempt operation	✓	10.3141/2128-03
Priority Time to Green	Characterize effectiveness of transit signal priority (or other forms of priority based control)	✓	(Monograph only)
Controller Ping Response	Maintain communication systems	✓	10.3141/2355-03
Data Completeness	Maintain communication systems	✓	10.3141/2355-03
Detector Failure Heat Map	Maintain detection systems		Unpublished
Corridor Travel Time	Evaluate performance of a corridor signal system	✓	10.3141/2192-04
Segment Speed	Evaluate performance of a corridor signal system		Unpublished



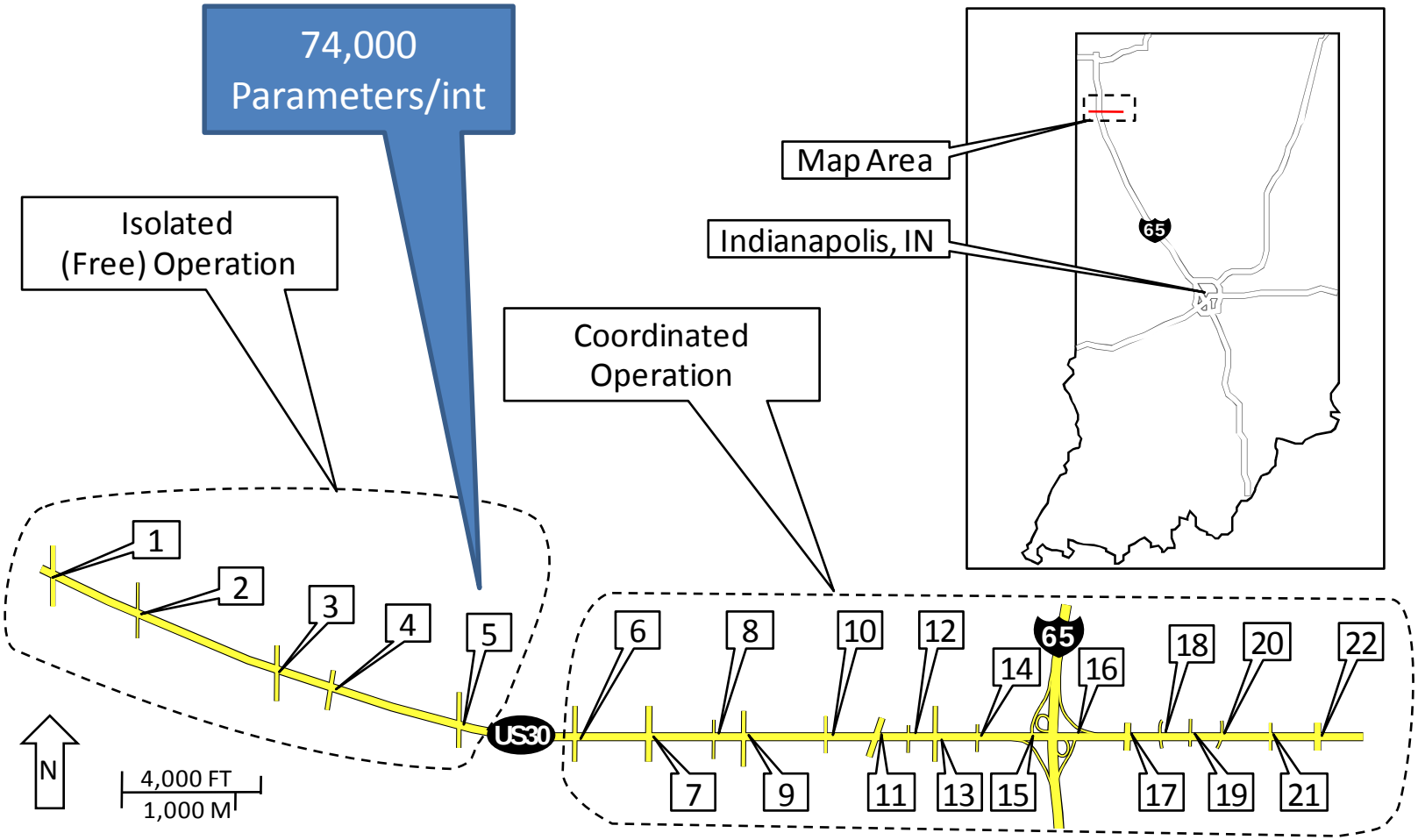
This workshop is about sharing best practices and developing shared vision



State of Signal Performance Measures Research



Typical Corridor (22 Intersections)



Traffic Signal Timing Process

Opportunity

Workshop Message

I. Define Objectives, Assess and Prioritize activities by Time of Day and location

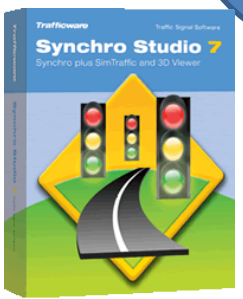
II. Assemble relevant data to support timing and documentation objectives

III. Software Modeling

IV. Timing Design and Documentation

V. Deployment

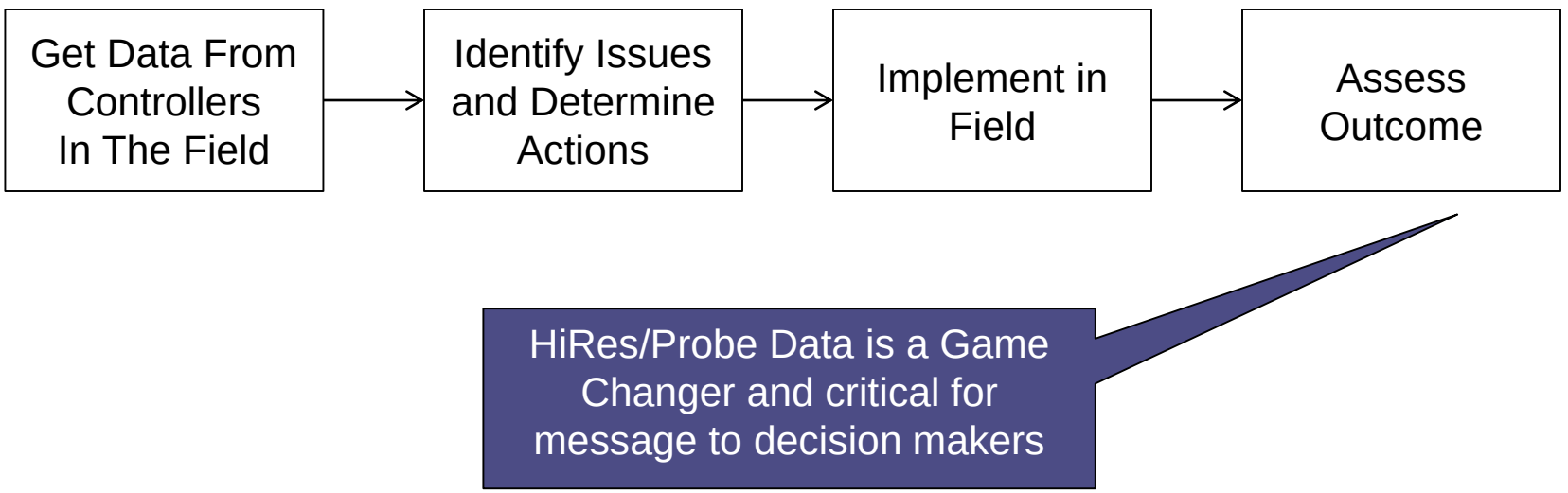
VI. Assess



Changing the System Management Model

Existing Model:

New Model:



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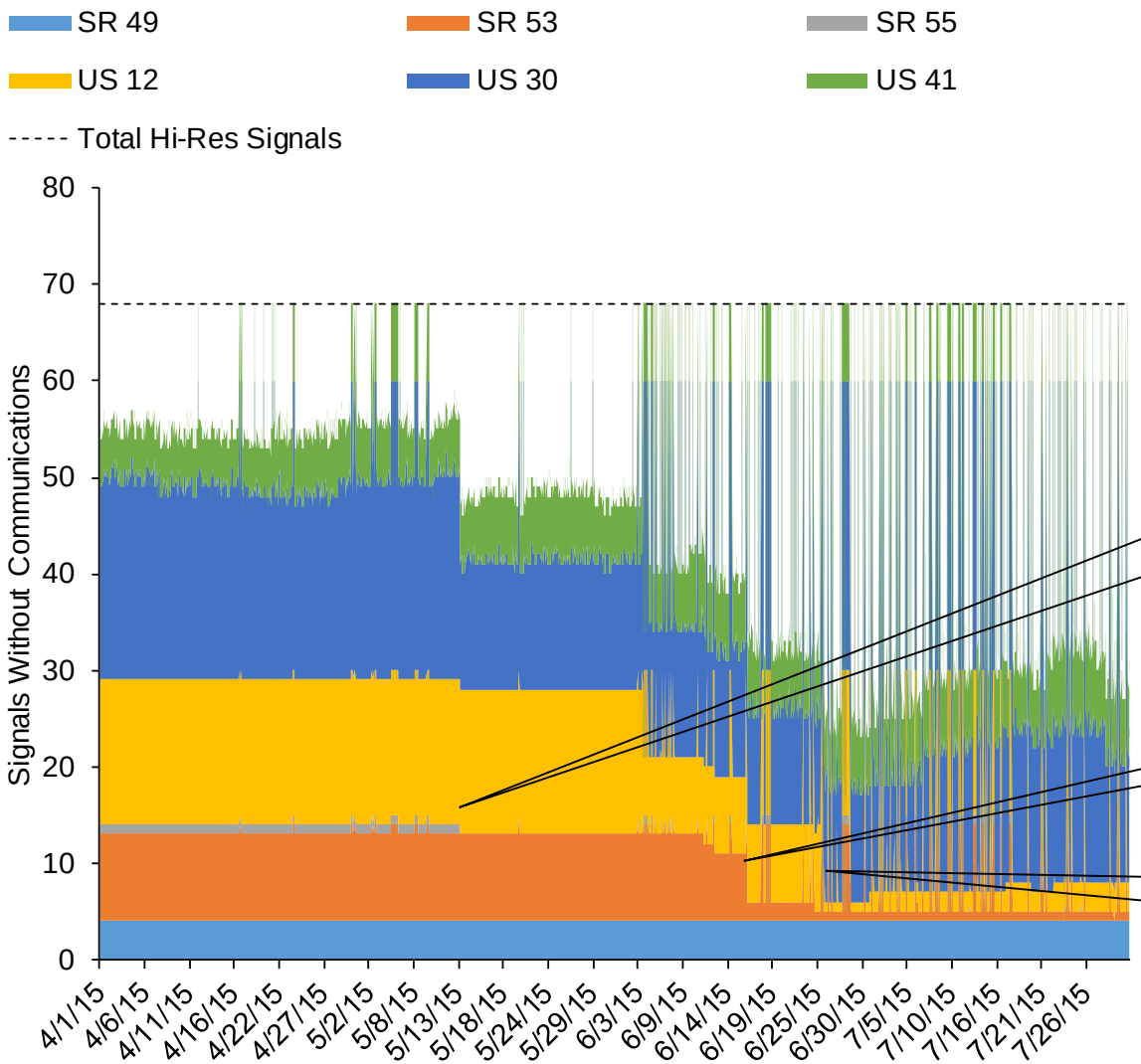
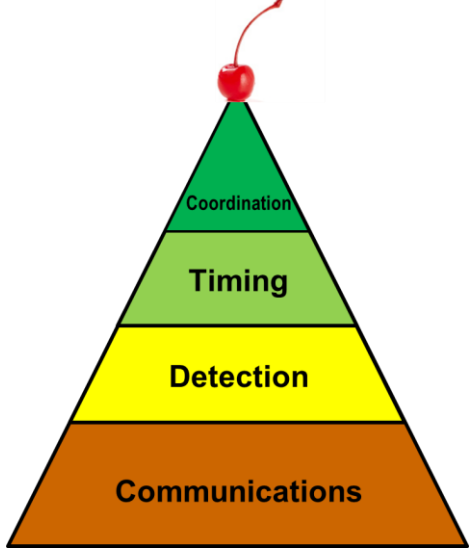
Communication “Ticker”





1. Fixed SR 49 ~ May 15

2. Substantial imp. on SR 53 ~ June 15

3. Substantial imp. on US 12 ~ June 15

50 % Improvement in 3 months

4-month plot of signal communications failures for LaPorte district

Messages

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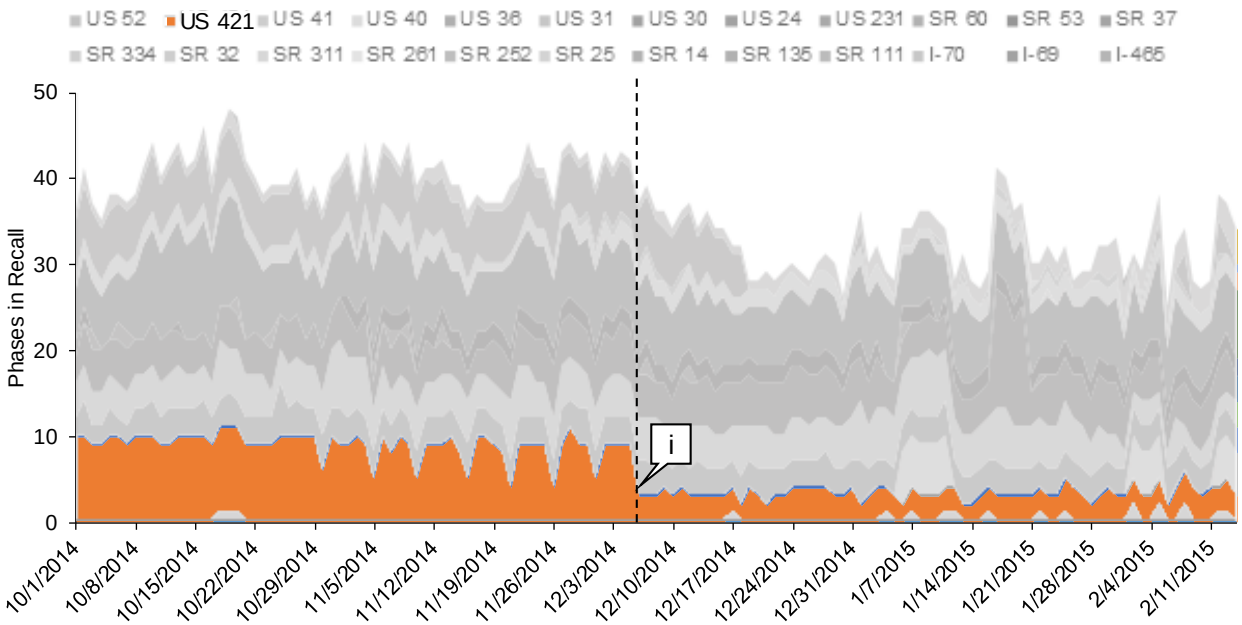
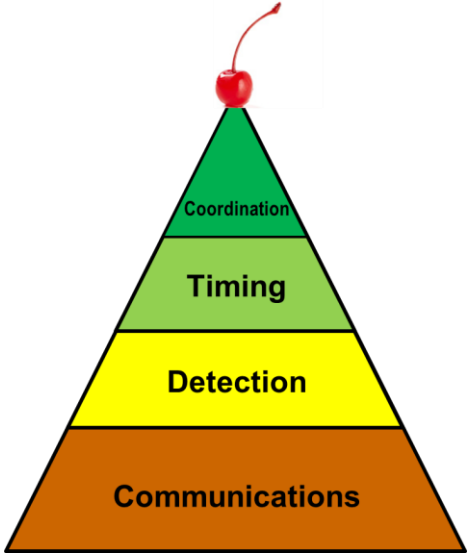
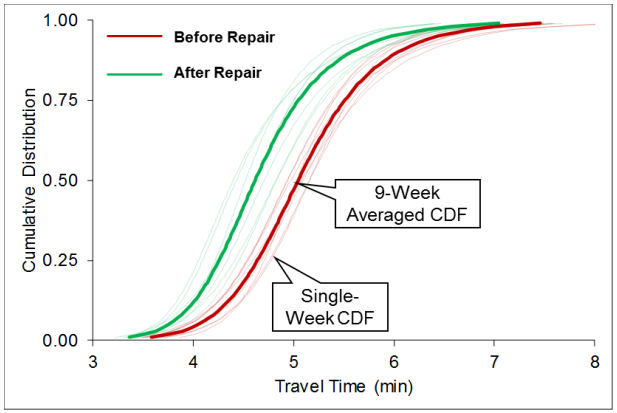
Detector “Ticker”





1. Replaced “missing” cards in Dec 2014



- $900,000 in annual user benefits

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Overview of Study Intersection

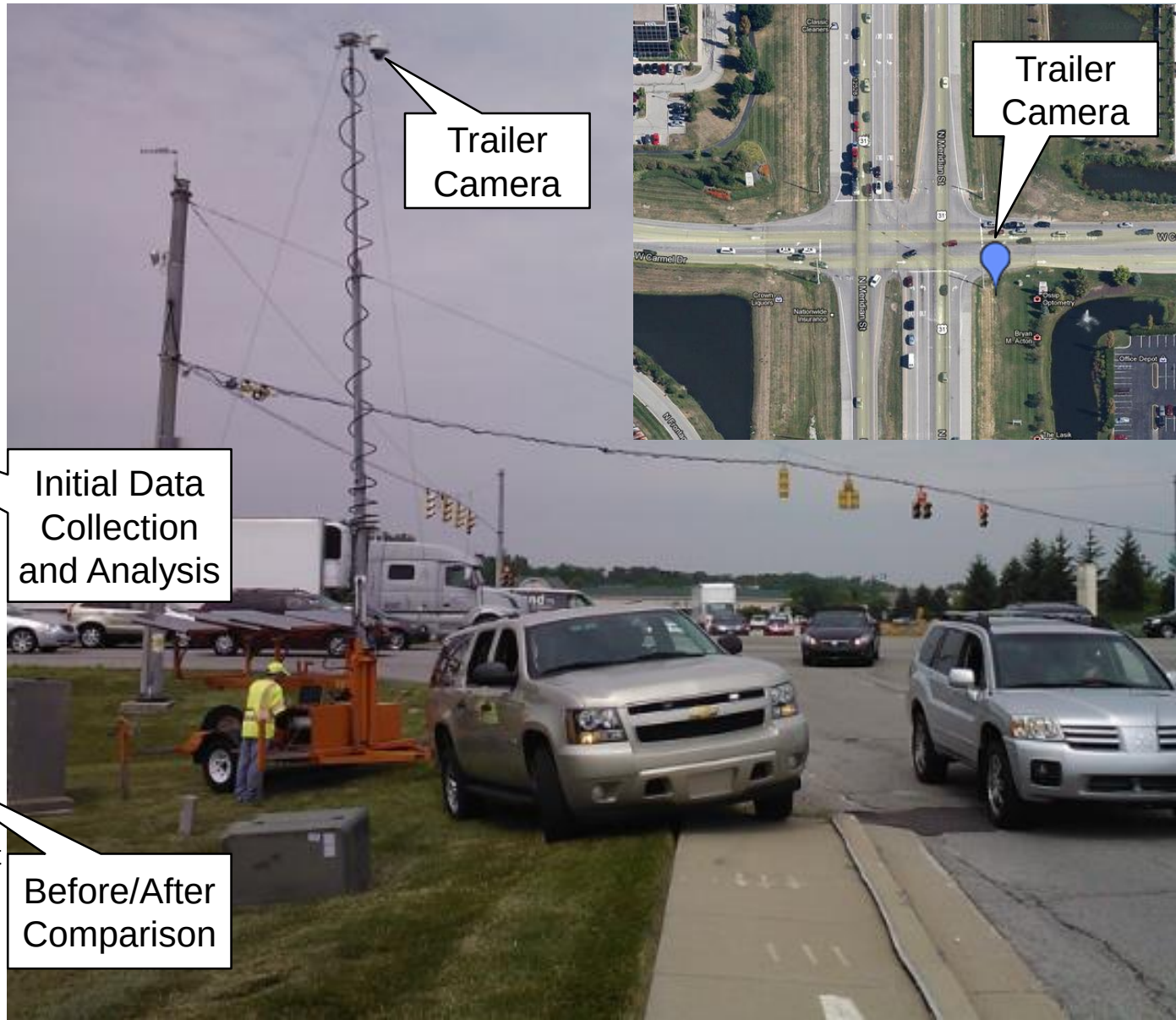
Trailer Camera Setup and Study Schedule

JUNE 2013						
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						

JULY 2013						
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	31			

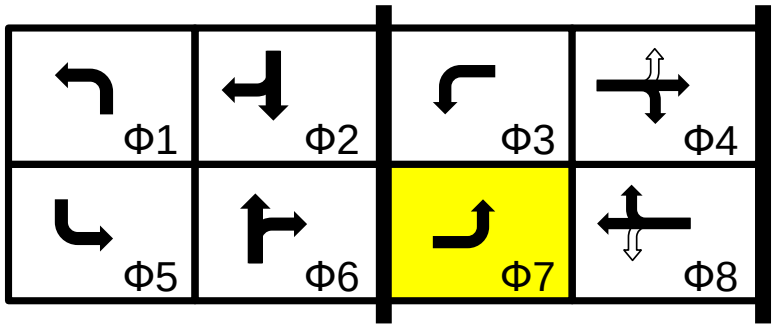
= Before Split Adjustment

= After Split Adjustment

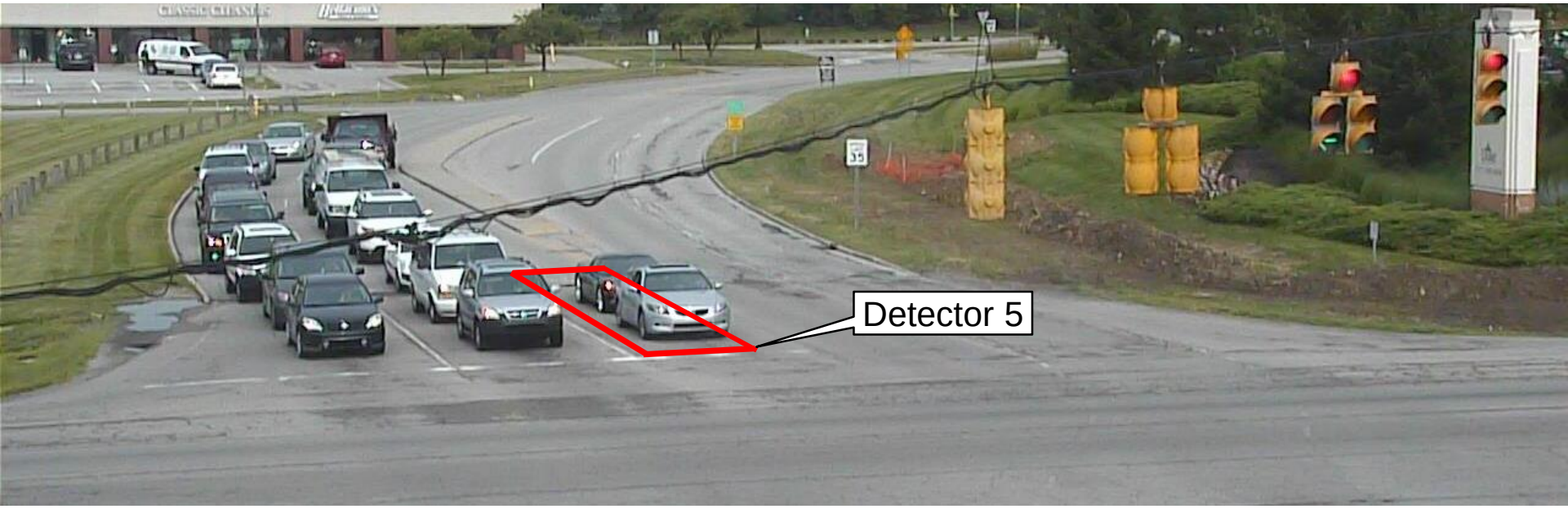


Phase 7 Extension Timer

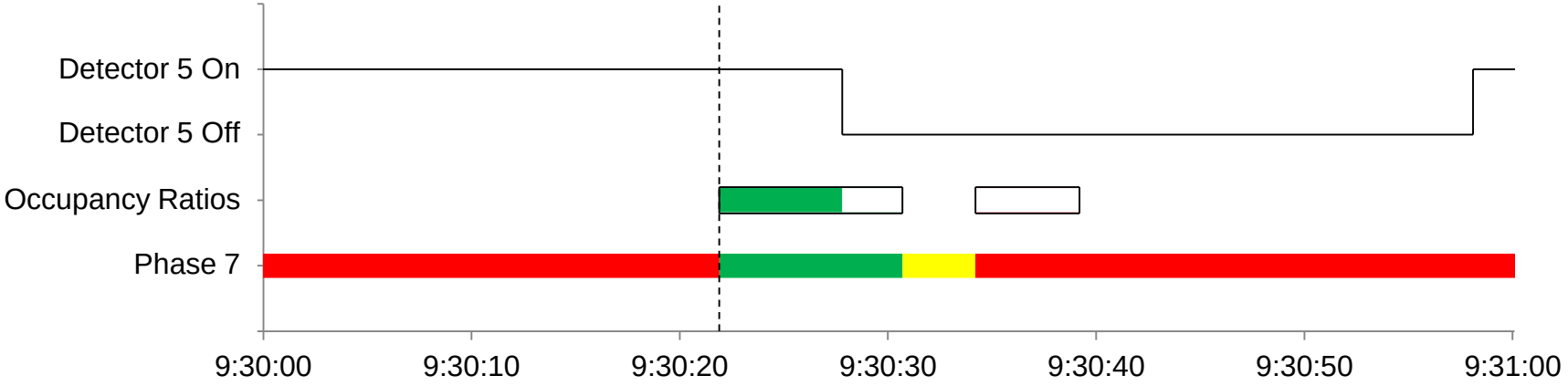
Extension Timer = 3.0 seconds



ROR_5 vs. GOR for an Undersaturated Split (Phase 7)

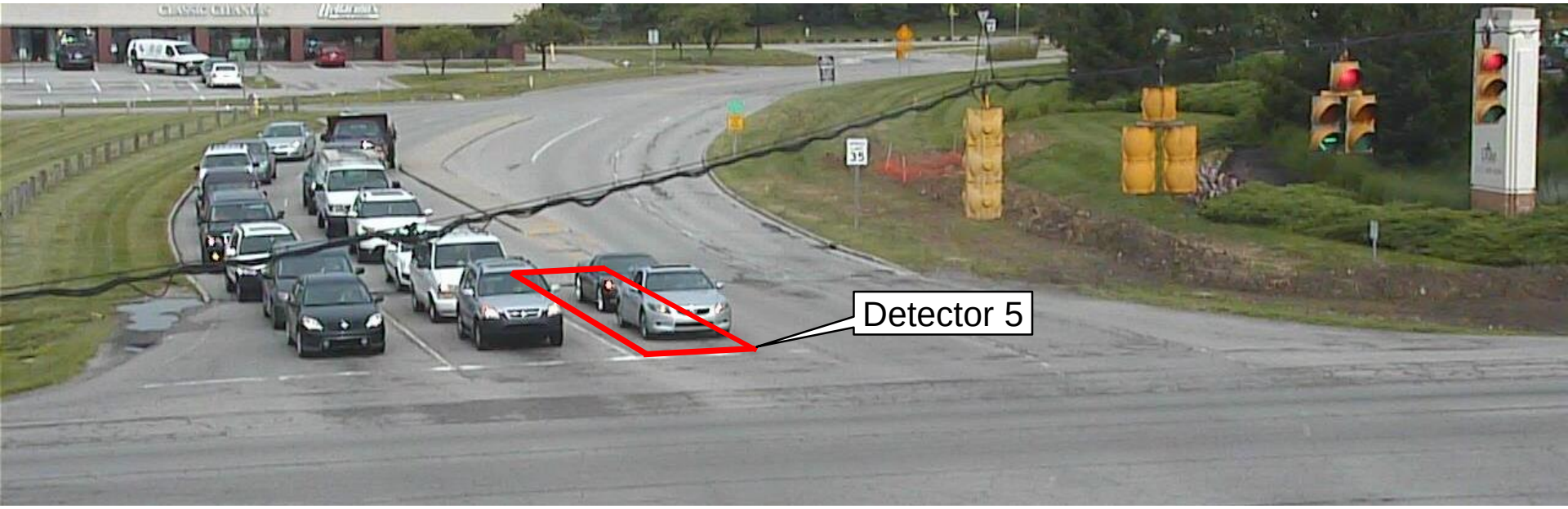


Start of Green (9:30:24.1)

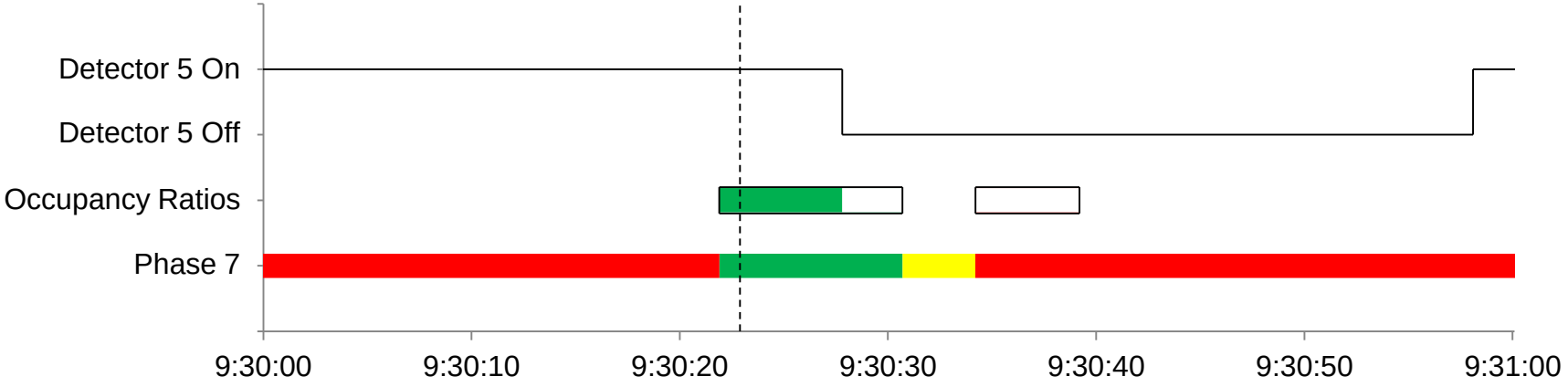


Calculation Illustration of GOR and ROR_5

ROR_5 vs. GOR for an Undersaturated Split (Phase 7)

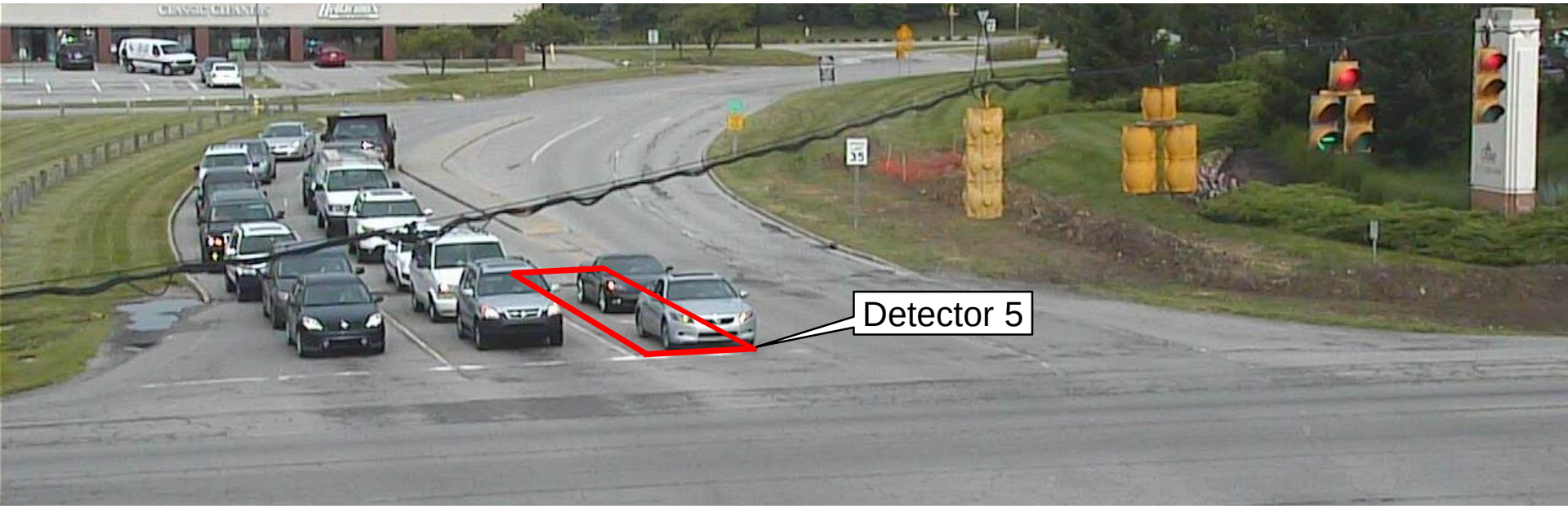


9:30:25.1

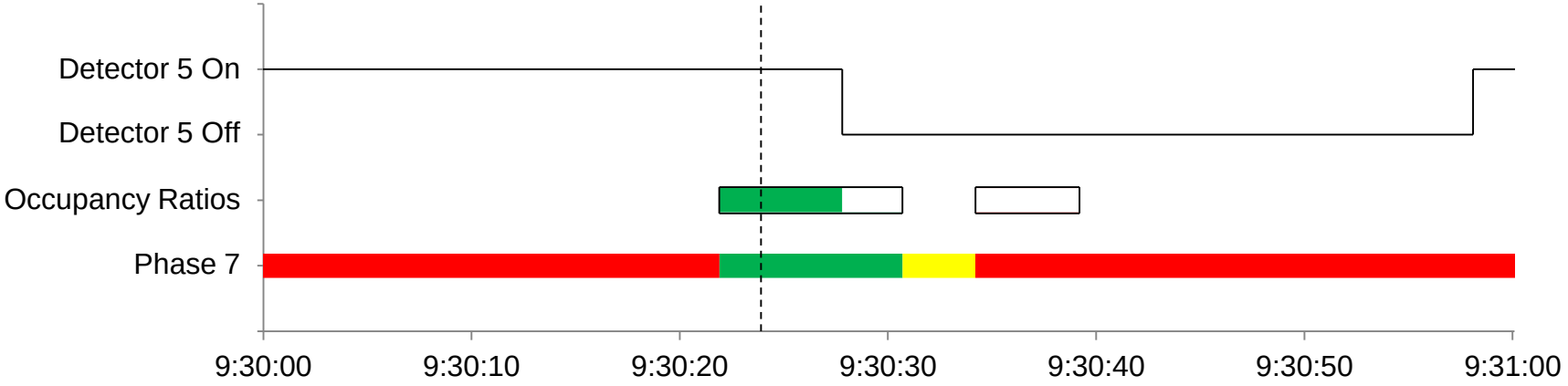


Calculation Illustration of GOR and ROR_5

ROR_5 vs. GOR for an Undersaturated Split (Phase 7)

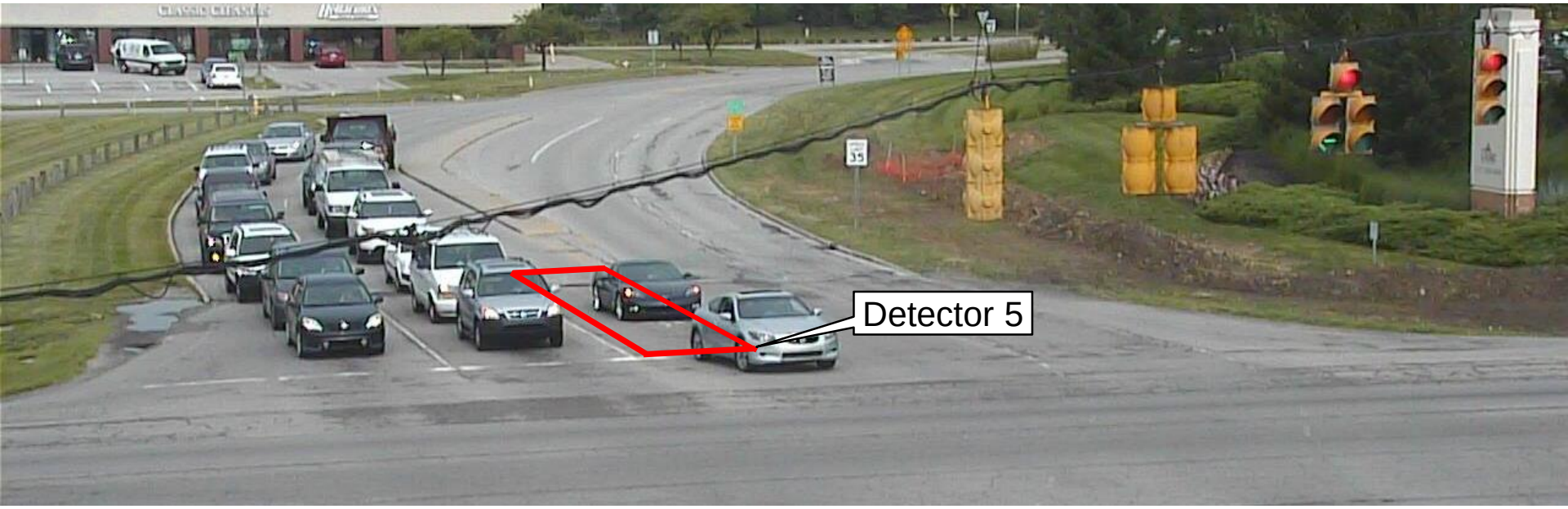


9:30:26.1

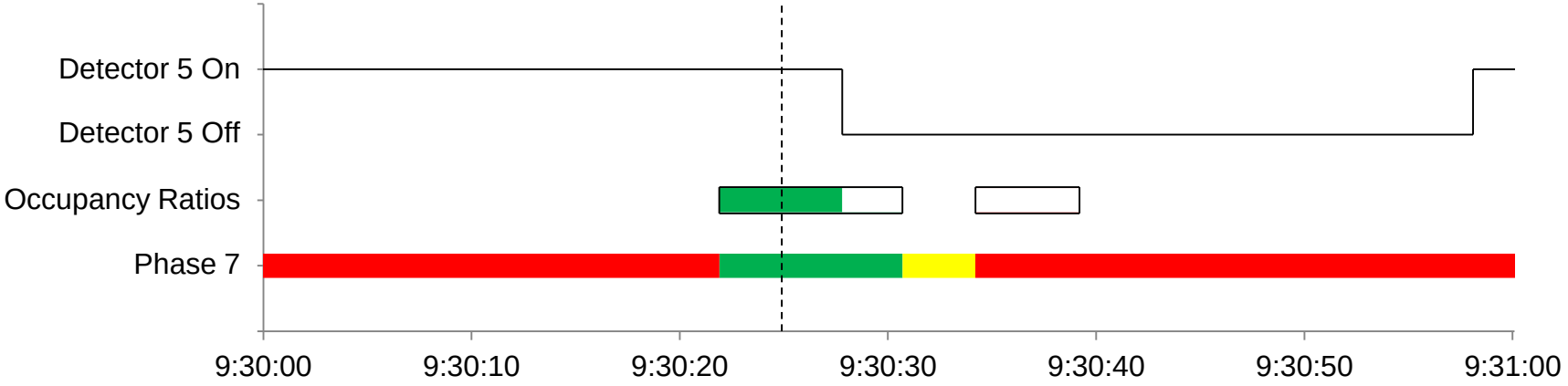


Calculation Illustration of GOR and ROR_5

ROR_5 vs. GOR for an Undersaturated Split (Phase 7)

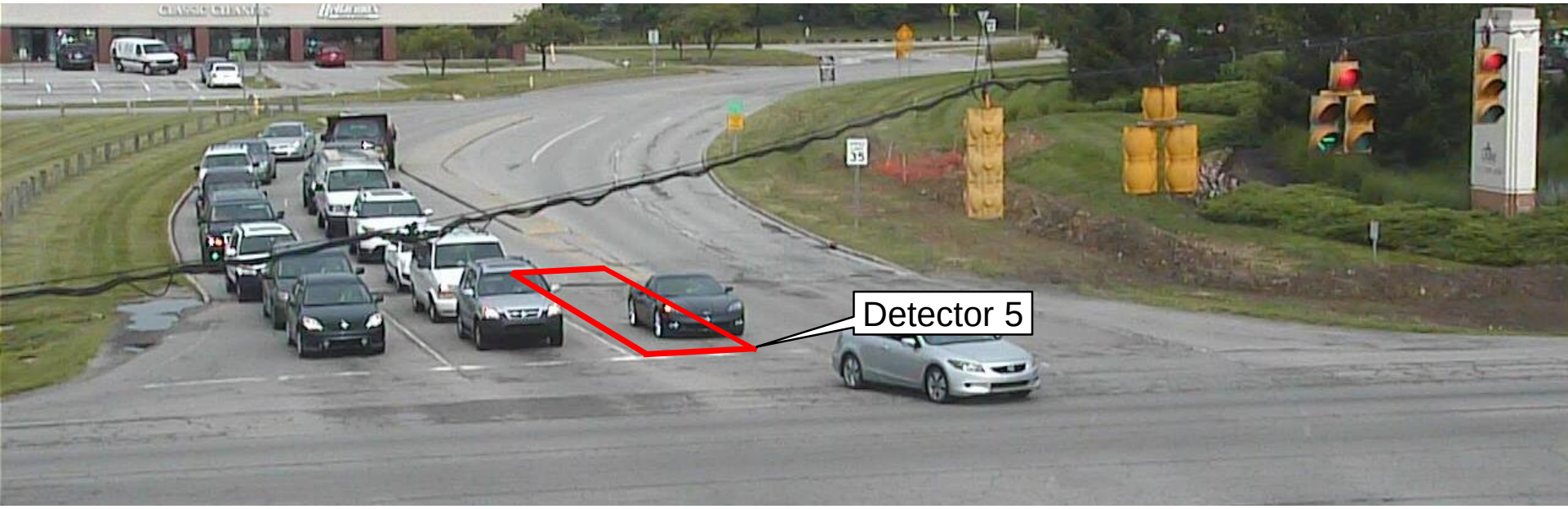


9:30:27.1

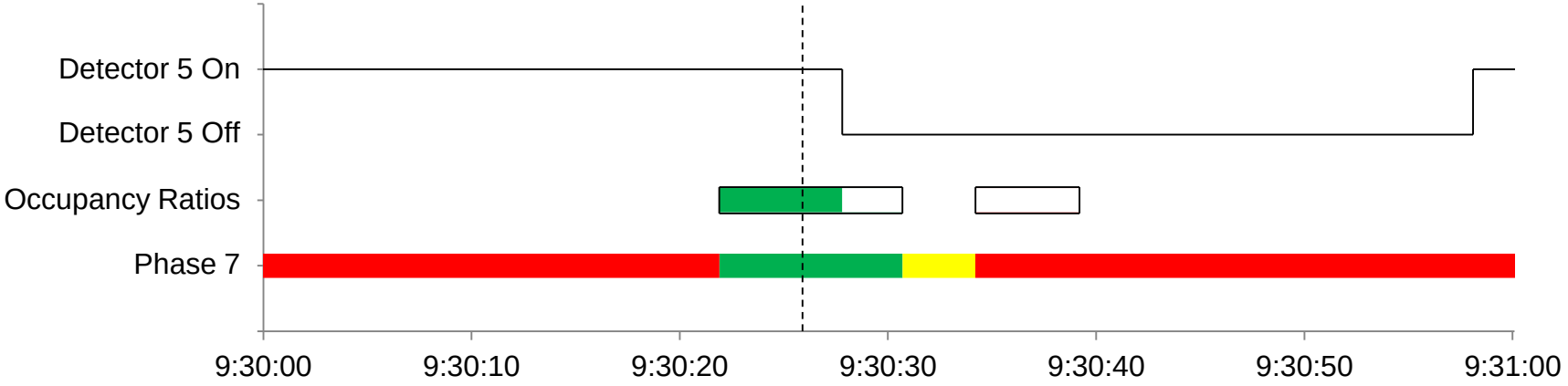


Calculation Illustration of GOR and ROR_5

ROR_5 vs. GOR for an Undersaturated Split (Phase 7)

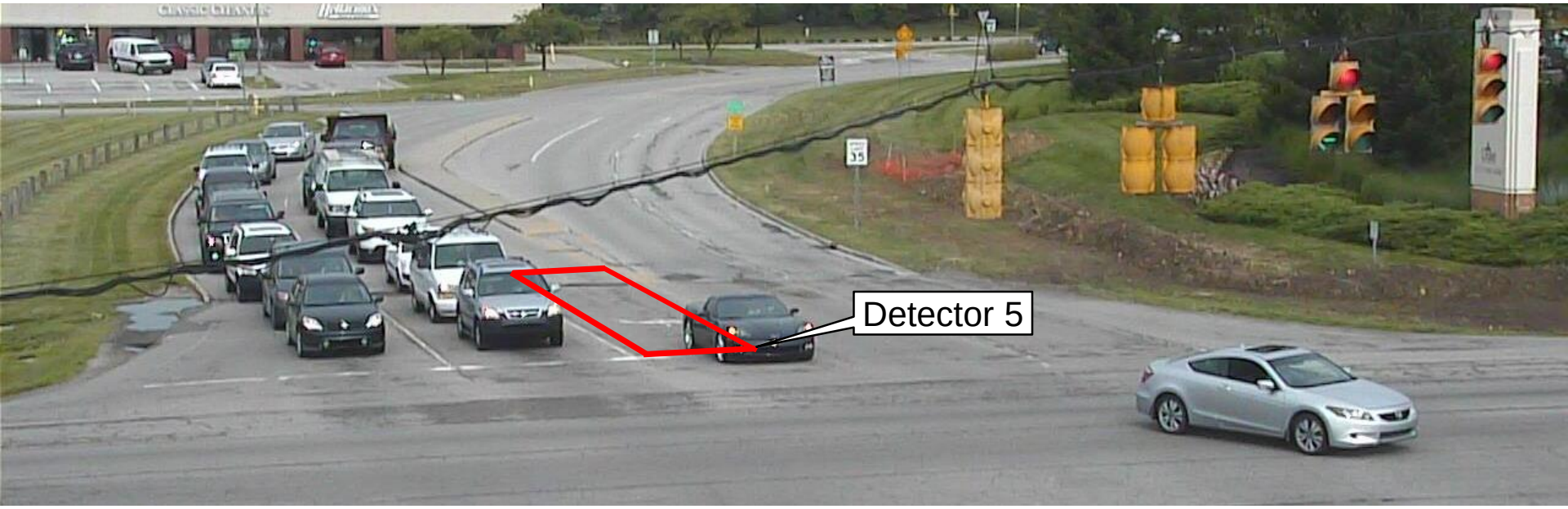


9:30:28.1

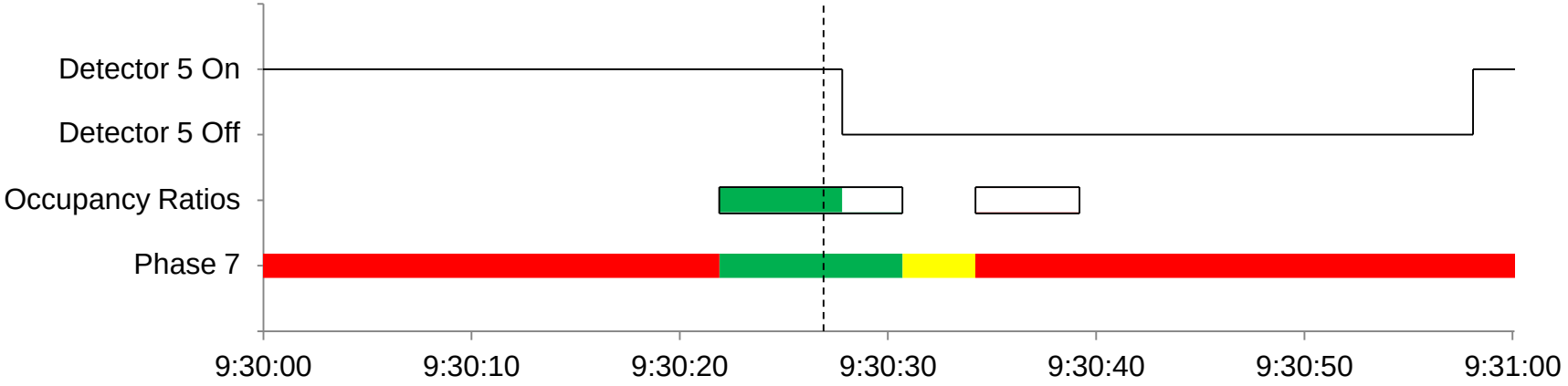


Calculation Illustration of GOR and ROR_5

ROR_5 vs. GOR for an Undersaturated Split (Phase 7)

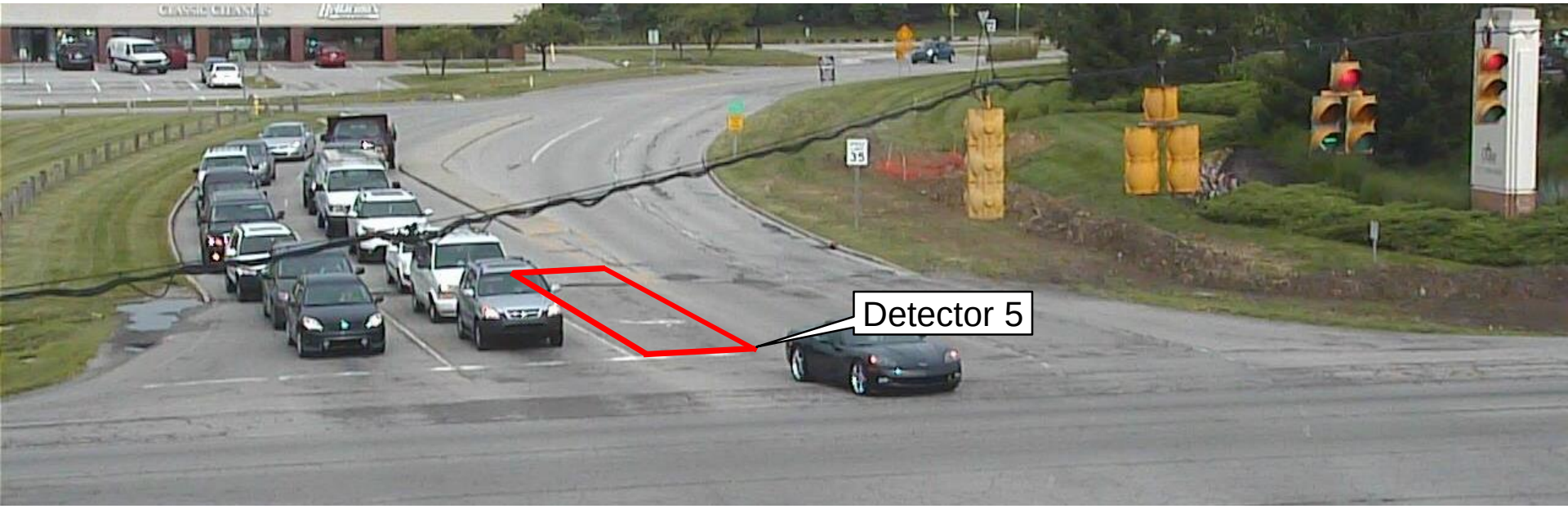


9:30:29.1



Calculation Illustration of GOR and ROR_5

ROR_5 vs. GOR for an Undersaturated Split (Phase 7)



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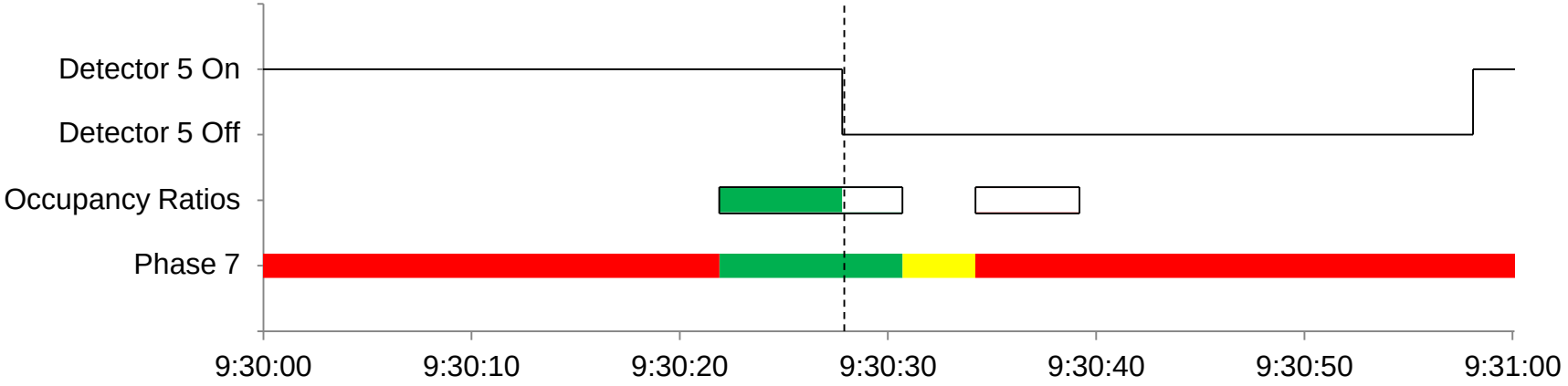
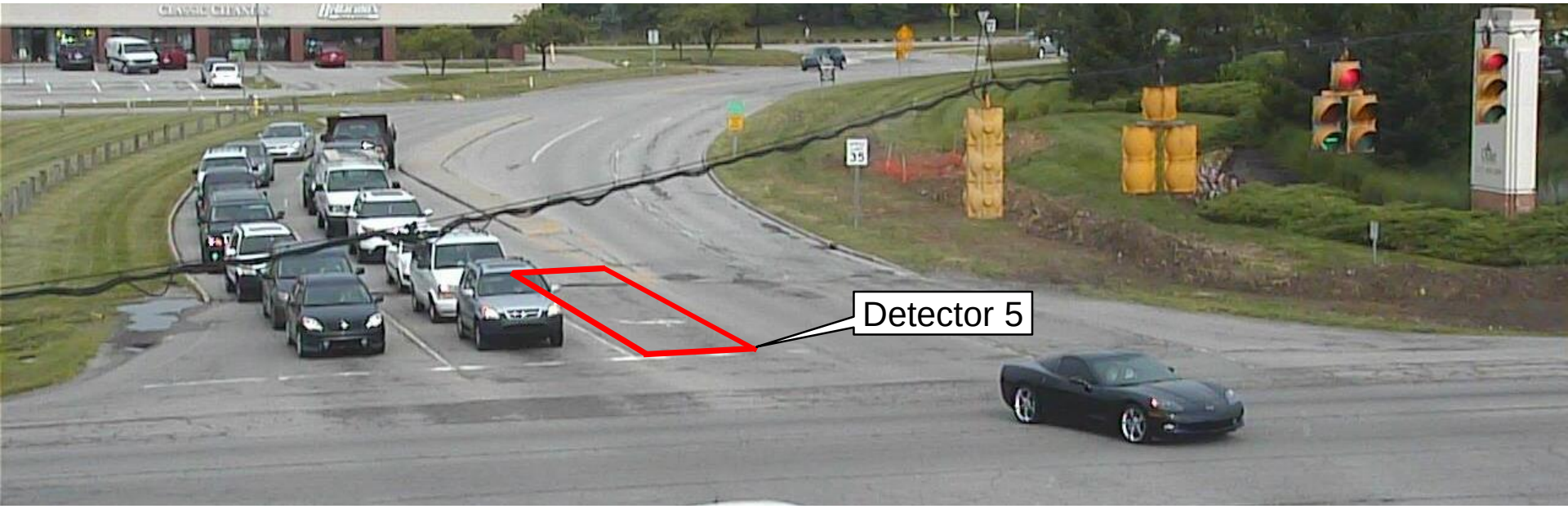
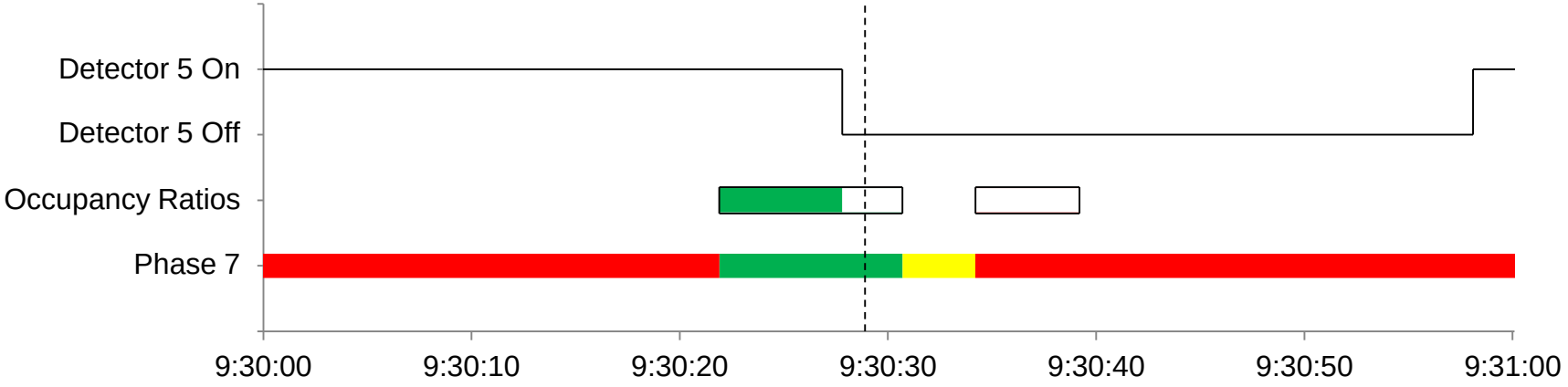


Calculation Illustration of GOR and ROR_5

ROR_5 vs. GOR for an Undersaturated Split (Phase 7)

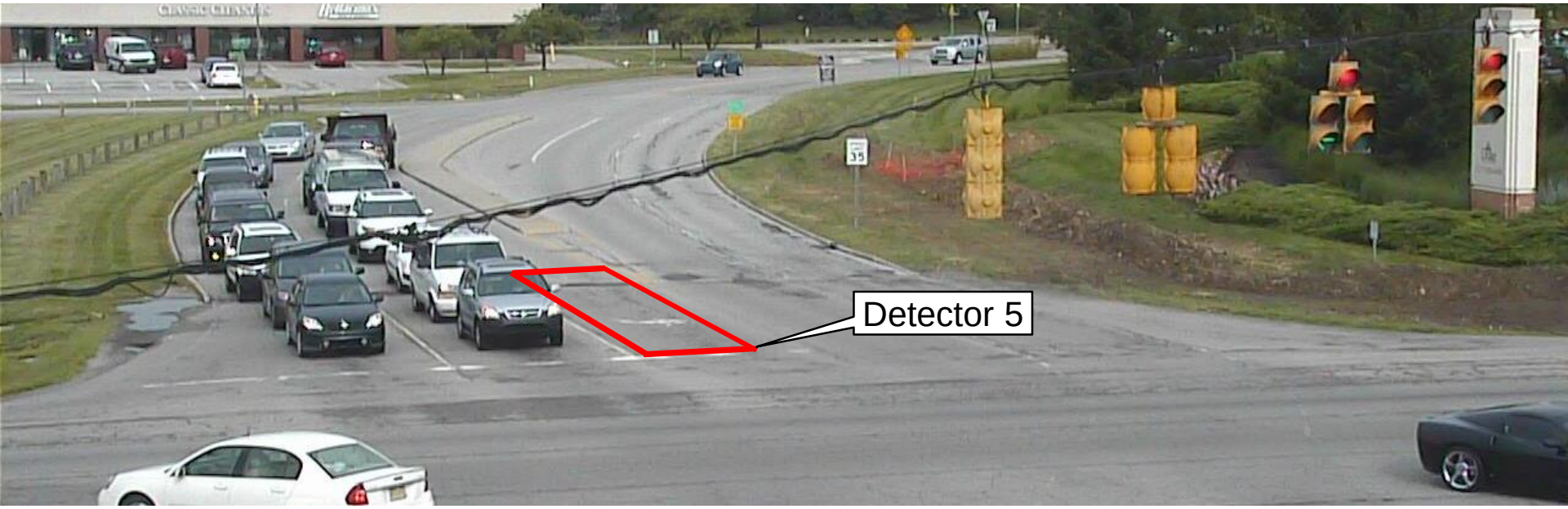


9:30:31.1

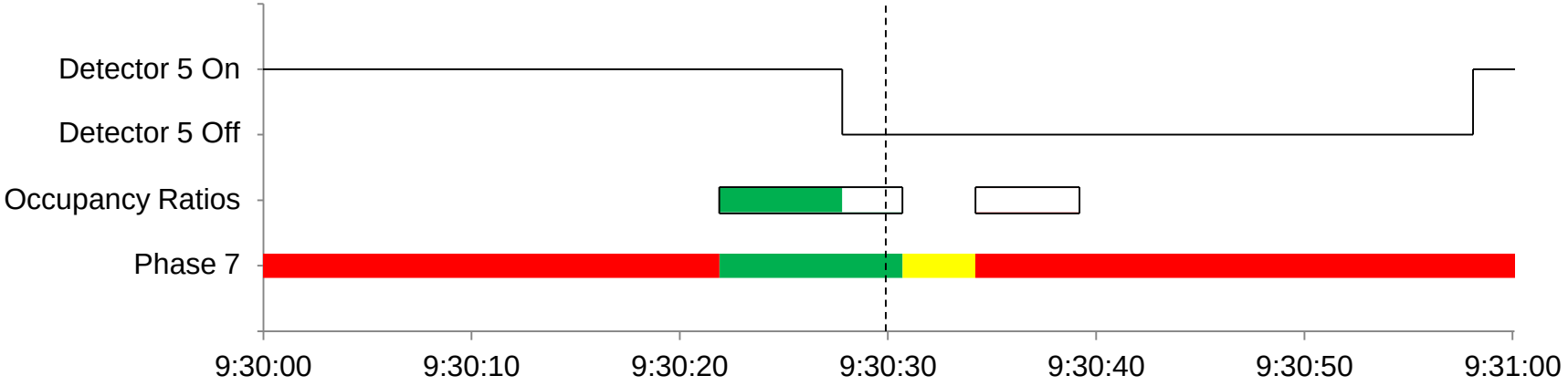


Calculation Illustration of GOR and ROR_5

ROR_5 vs. GOR for an Undersaturated Split (Phase 7)

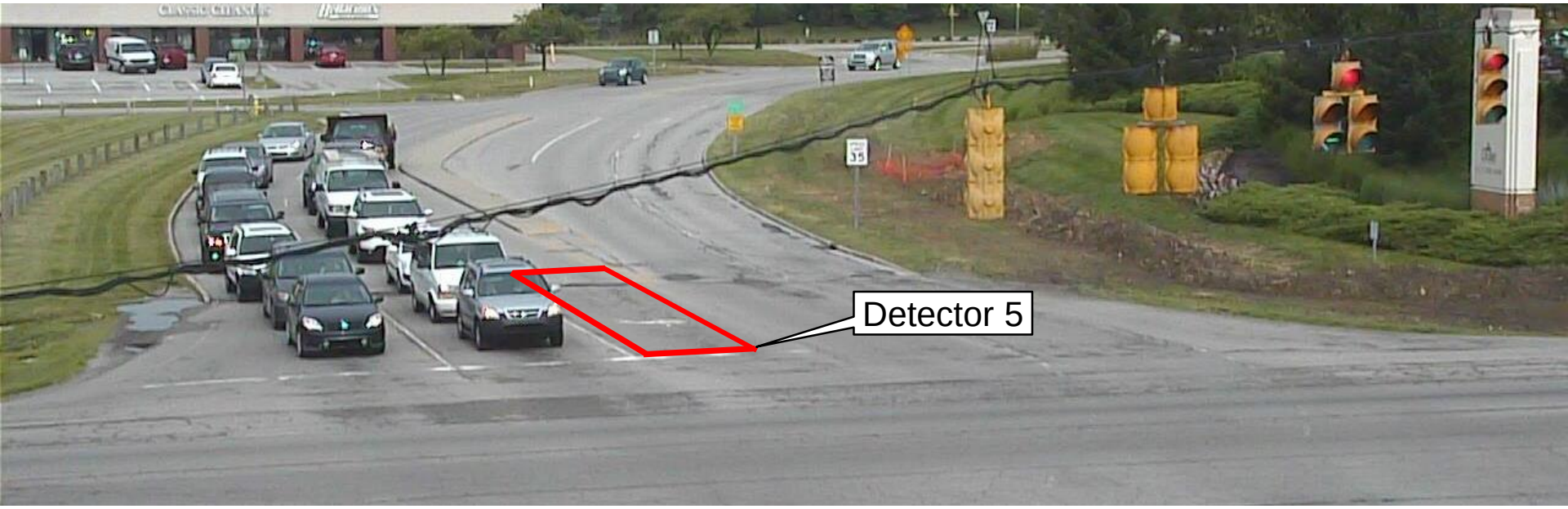


9:30:32.1

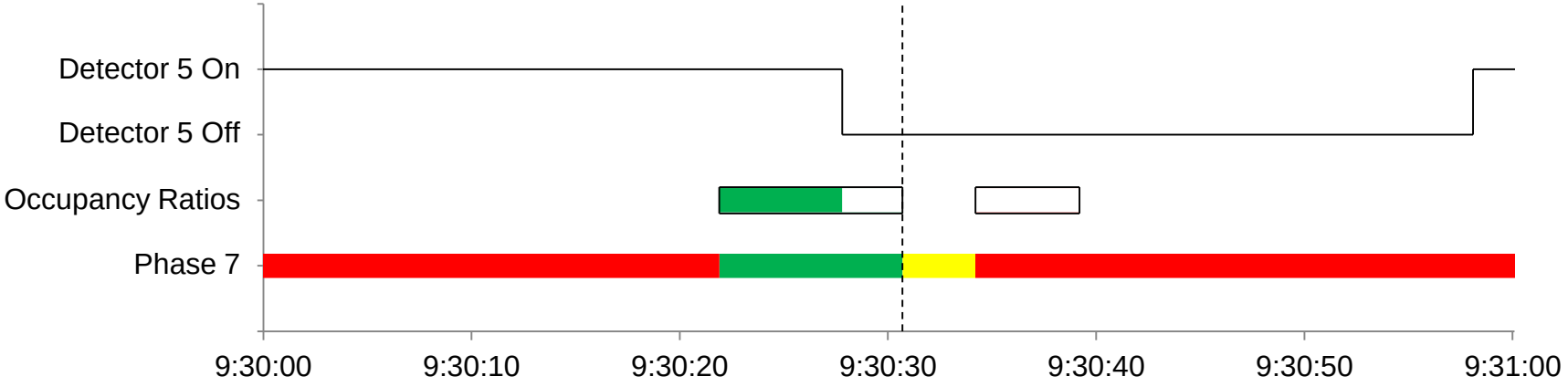


Calculation Illustration of GOR and ROR_5

ROR_5 vs. GOR for an Undersaturated Split (Phase 7)

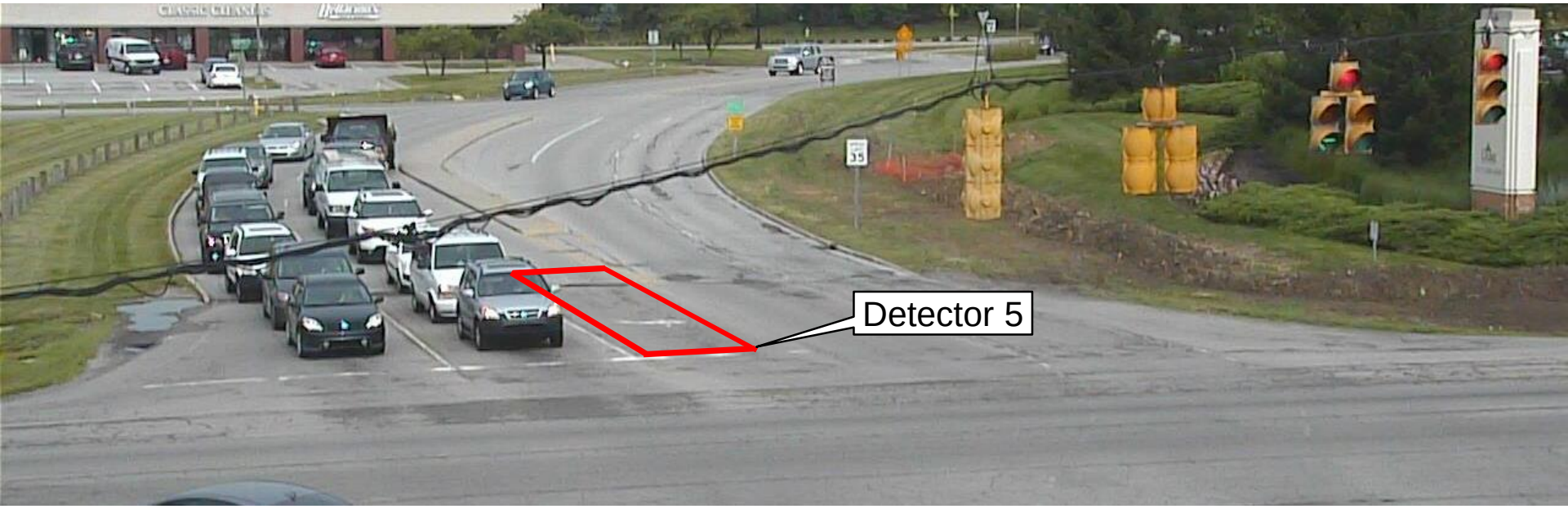


Start of Yellow (9:30:33.1)

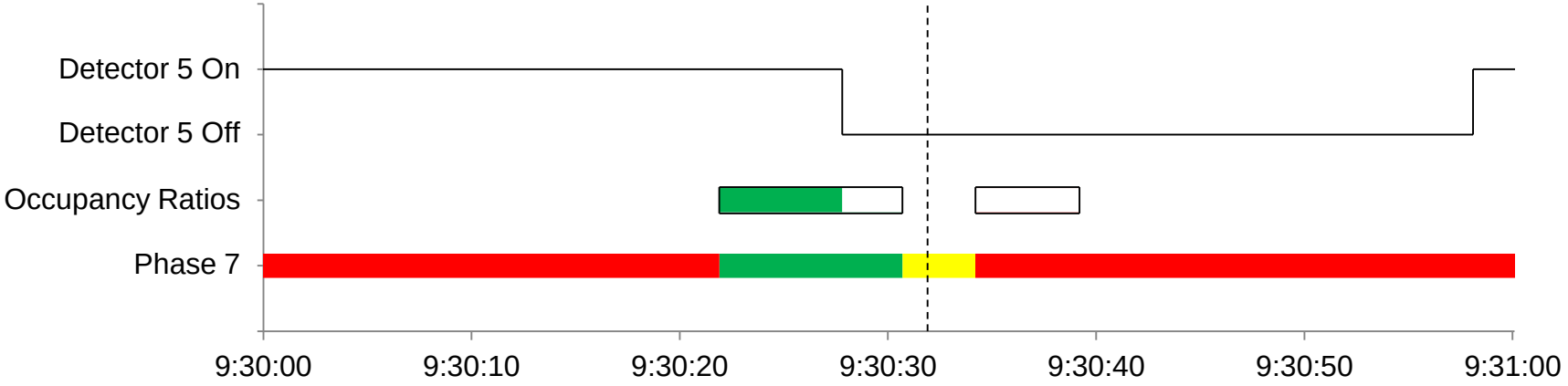


Calculation Illustration of GOR and ROR_5

ROR_5 vs. GOR for an Undersaturated Split (Phase 7)

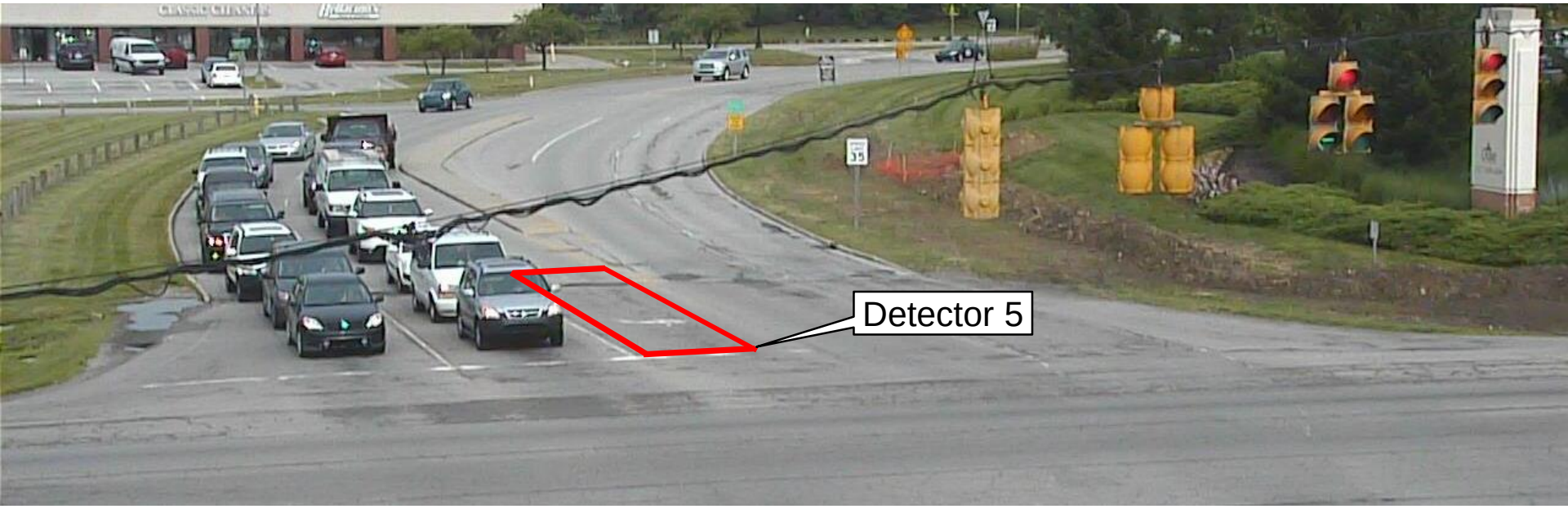


9:30:34.1

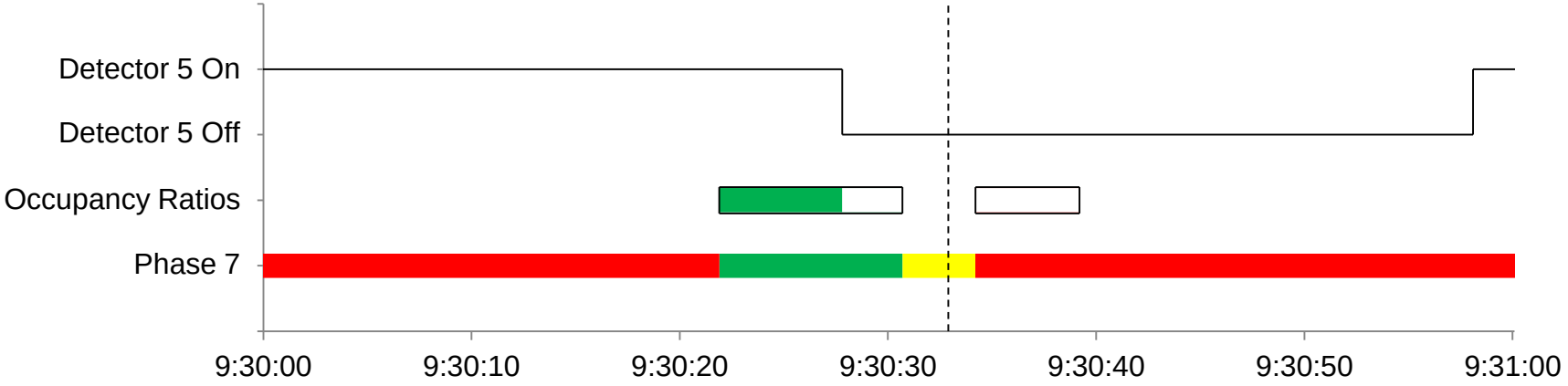


Calculation Illustration of GOR and ROR_5

ROR_5 vs. GOR for an Undersaturated Split (Phase 7)

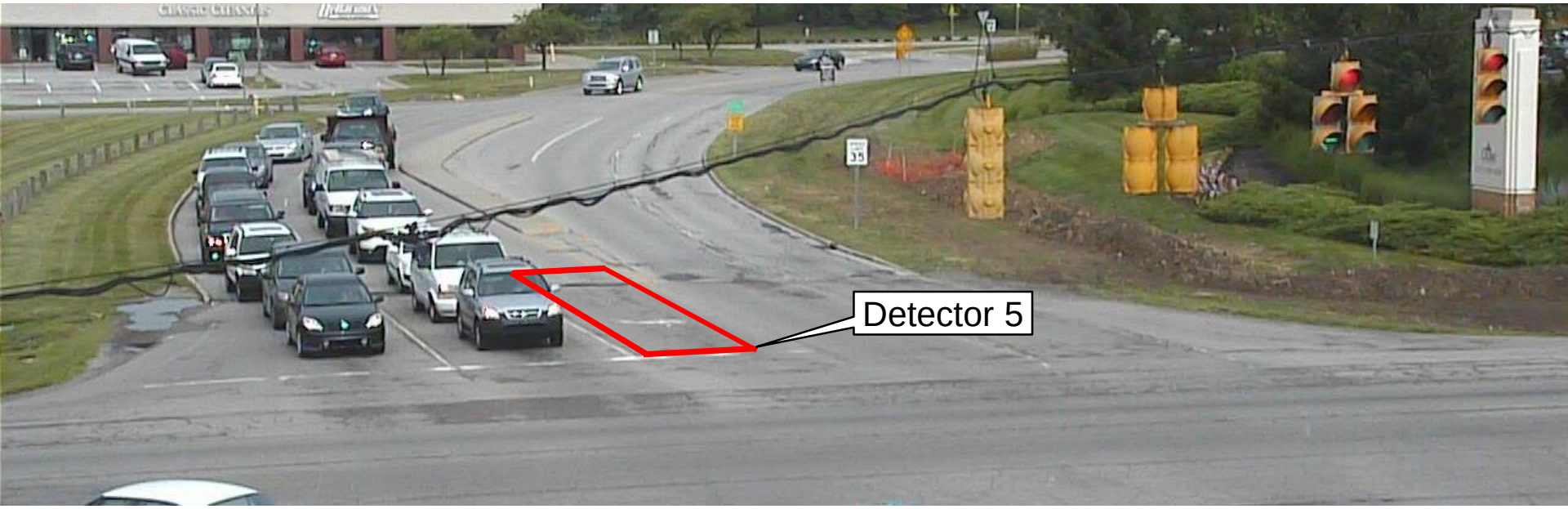


9:30:35.1

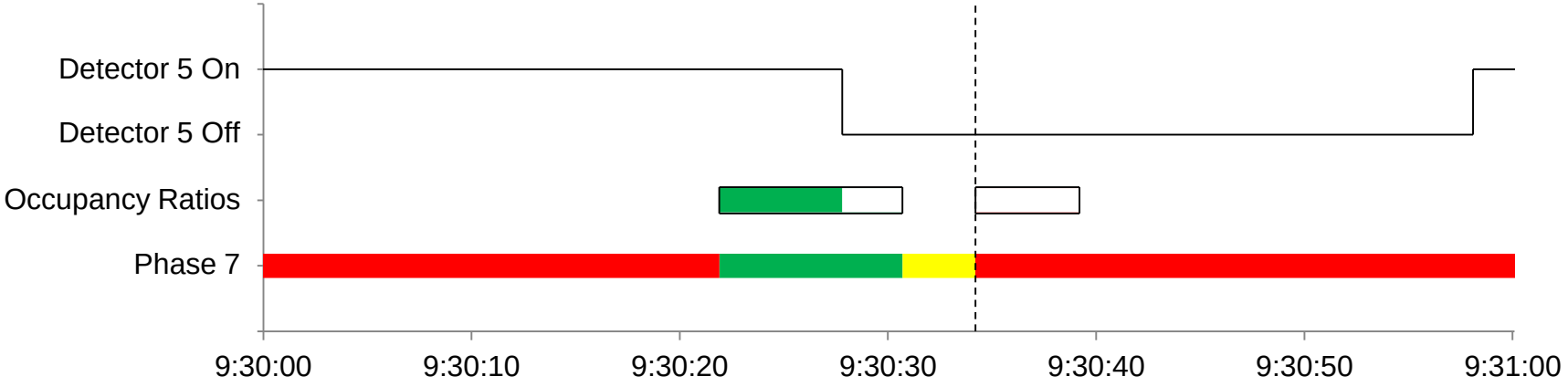


Calculation Illustration of GOR and ROR_5

ROR_5 vs. GOR for an Undersaturated Split (Phase 7)

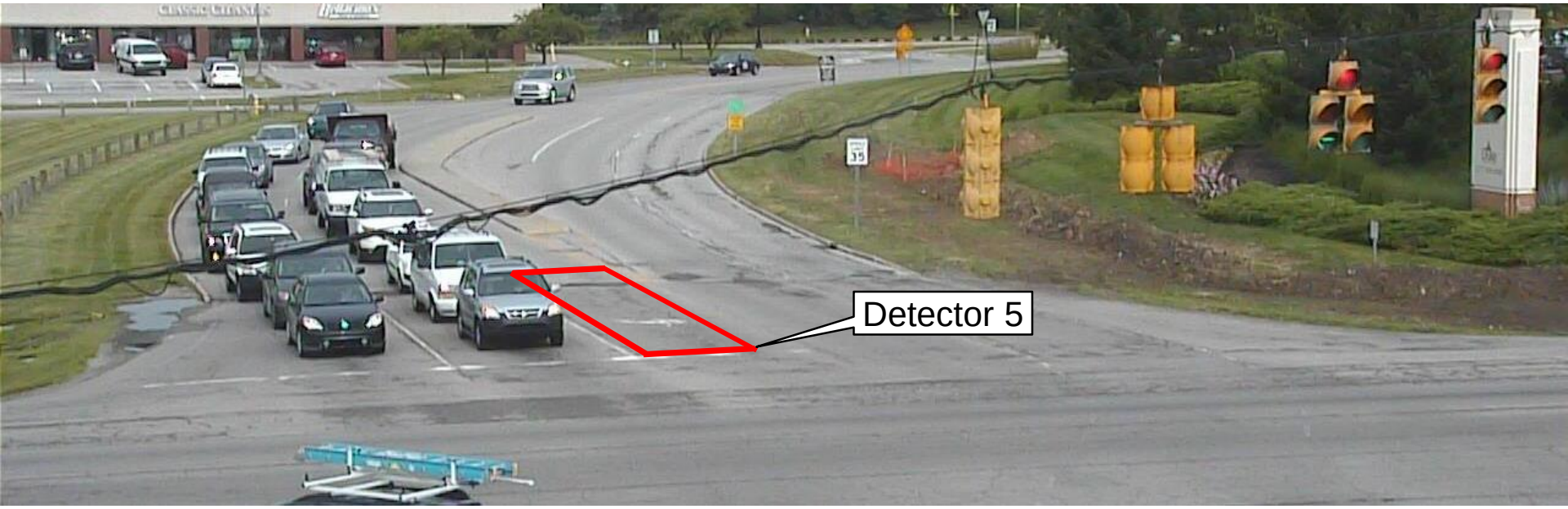


Start of Red (9:30:36.6)

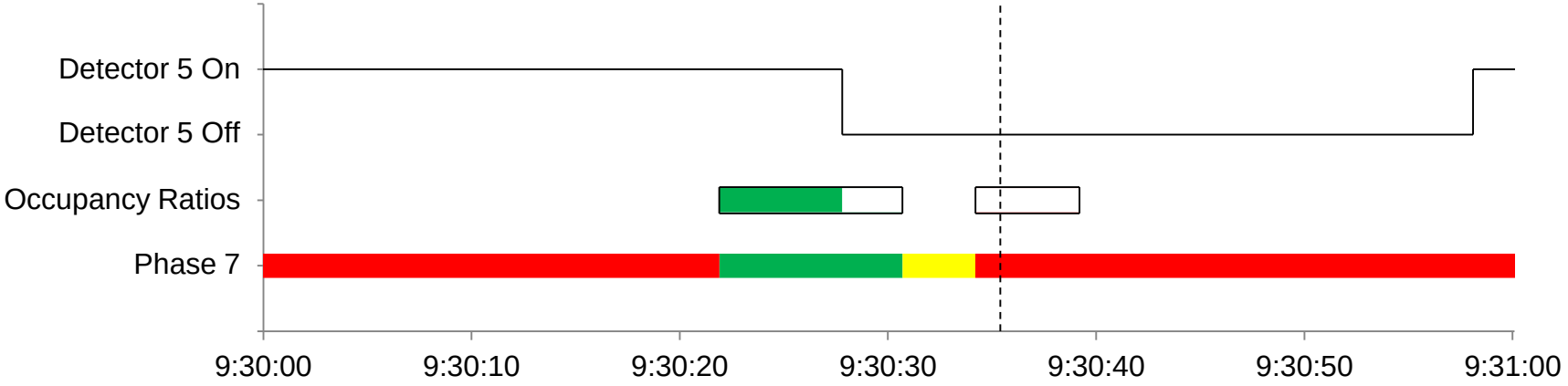


Calculation Illustration of GOR and ROR_5

ROR_5 vs. GOR for an Undersaturated Split (Phase 7)

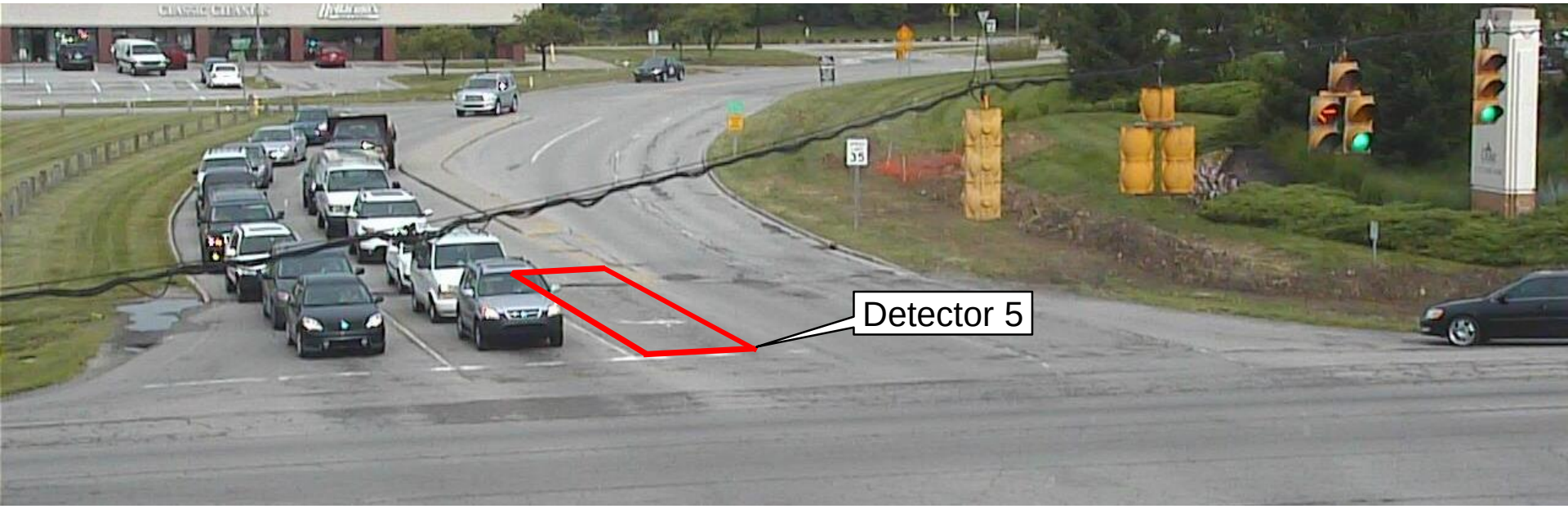


9:30:37.6

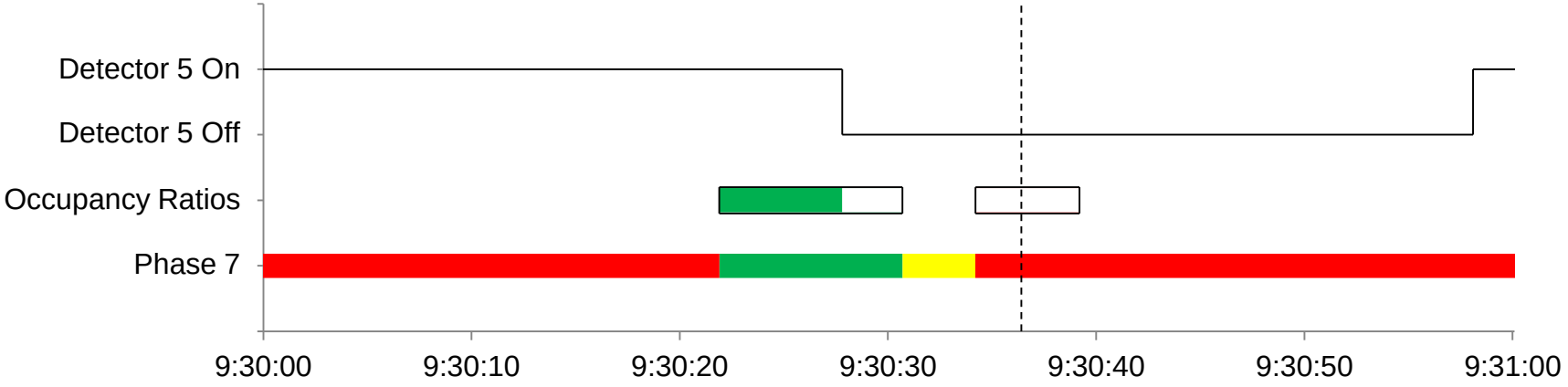


Calculation Illustration of GOR and ROR_5

ROR_5 vs. GOR for an Undersaturated Split (Phase 7)

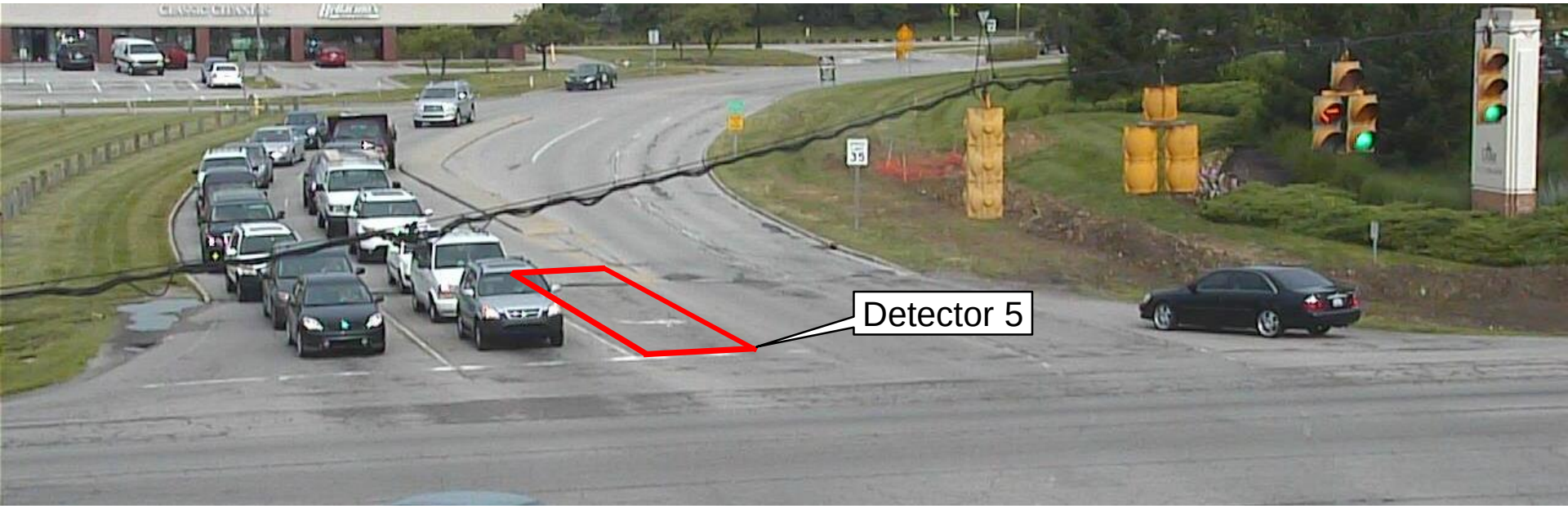


9:30:38.6

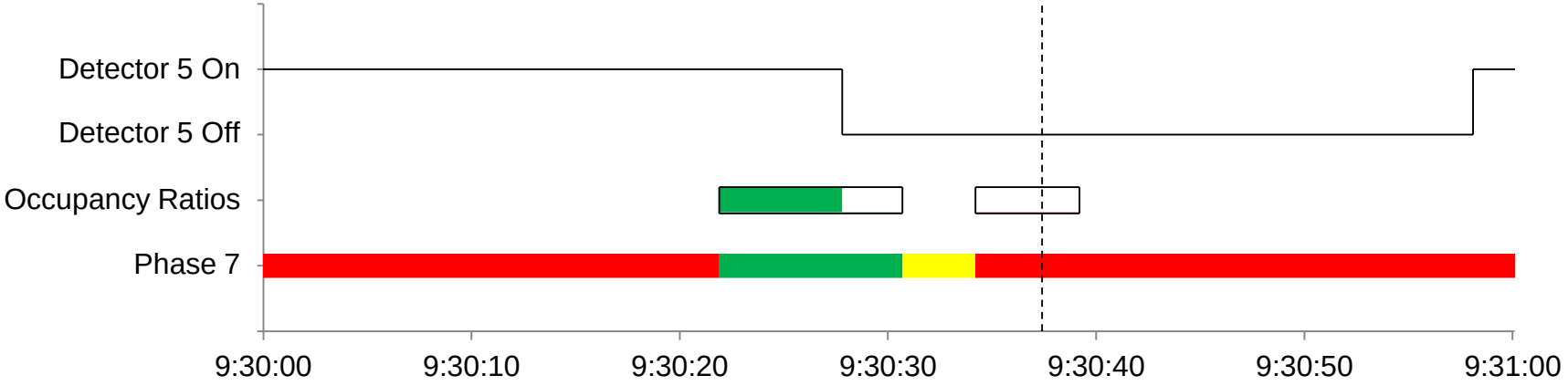


Calculation Illustration of GOR and ROR_5

ROR_5 vs. GOR for an Undersaturated Split (Phase 7)

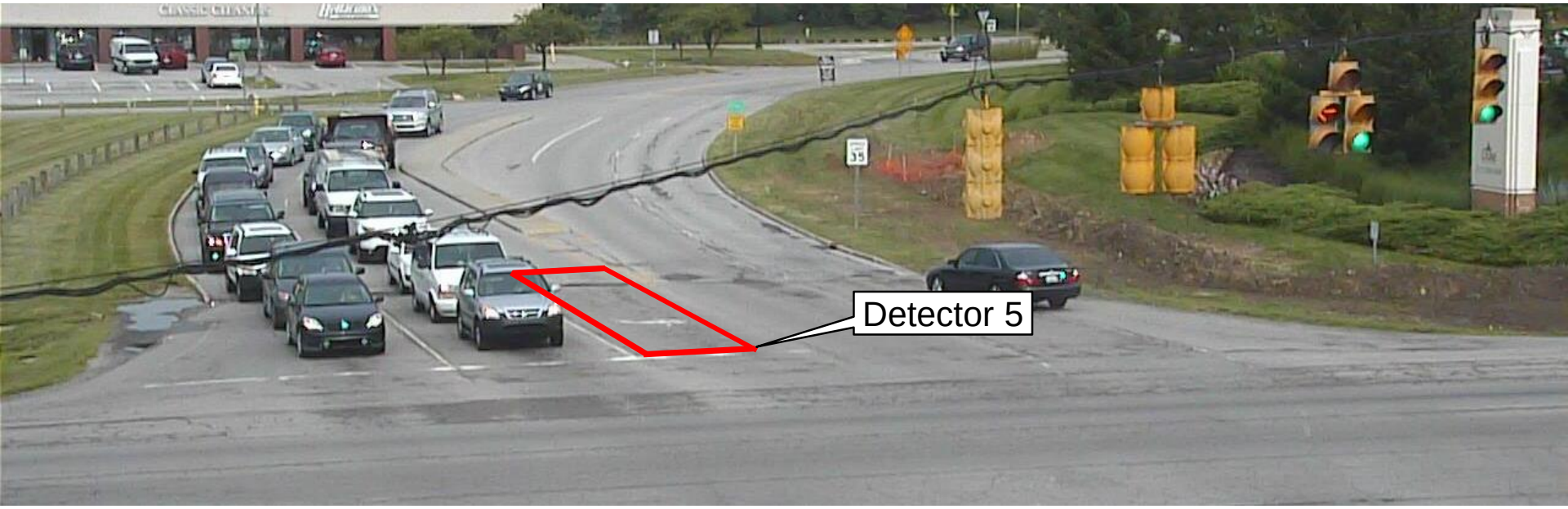


9:30:39.6

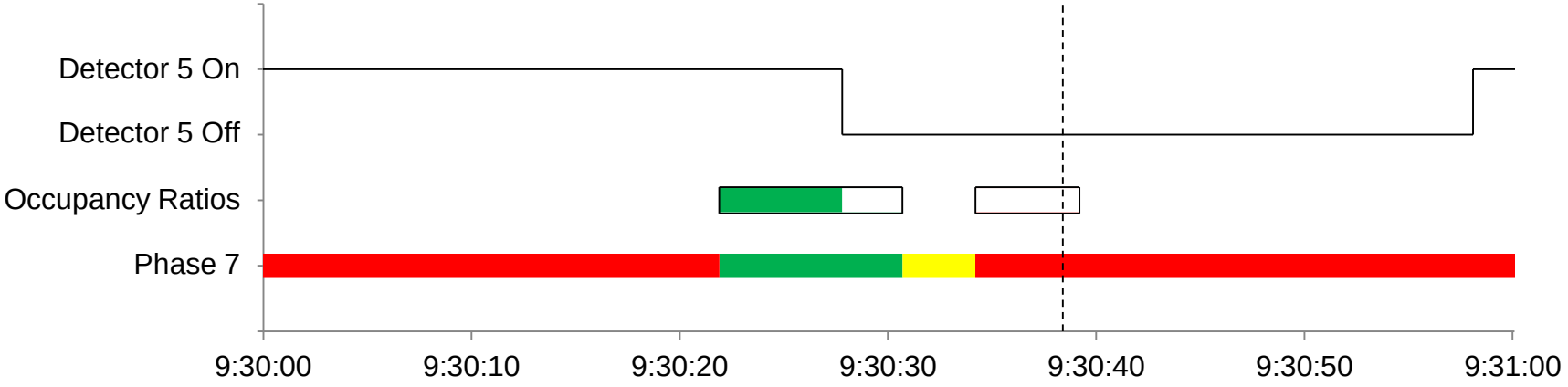


Calculation Illustration of GOR and ROR_5

ROR_5 vs. GOR for an Undersaturated Split (Phase 7)

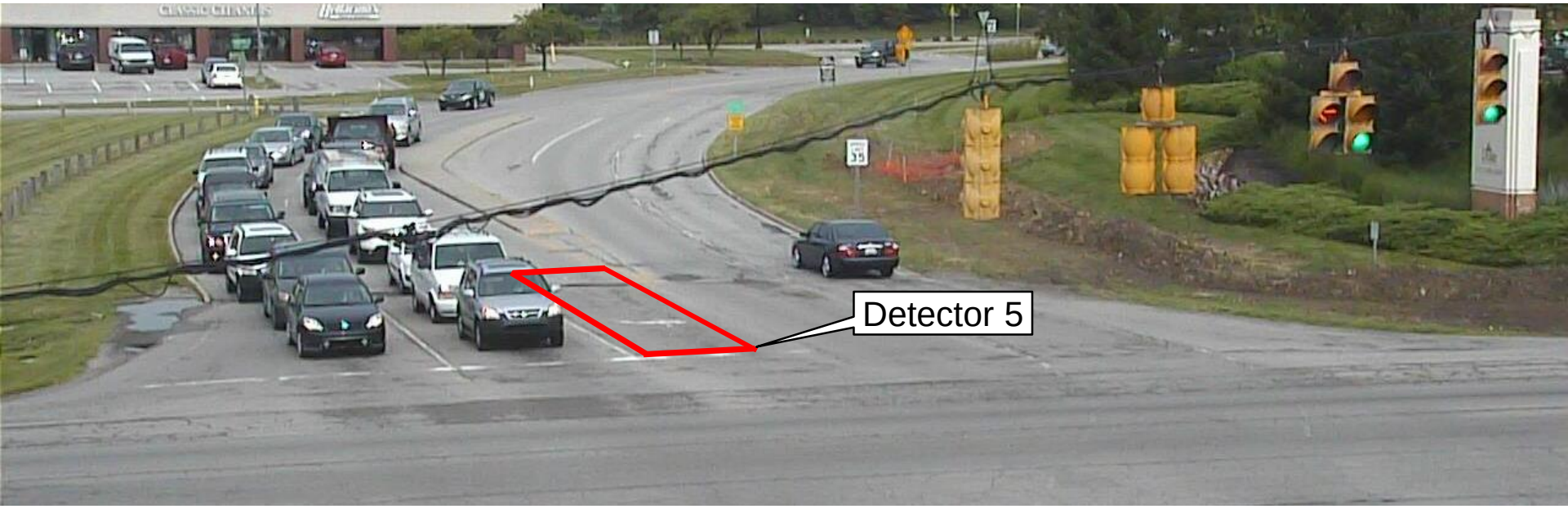


9:30:40.6

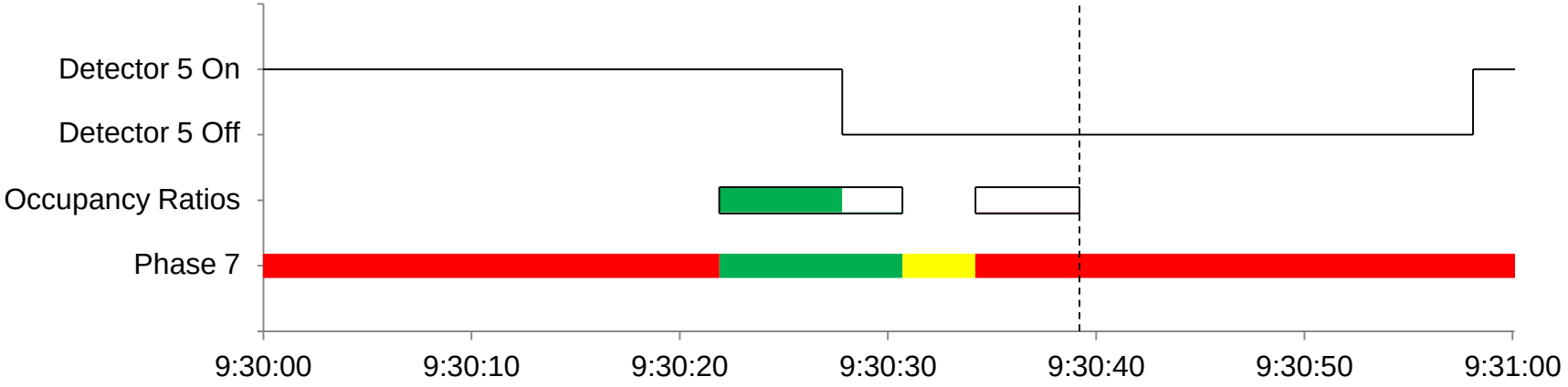


Calculation Illustration of GOR and ROR_5

ROR_5 vs. GOR for an Undersaturated Split (Phase 7)

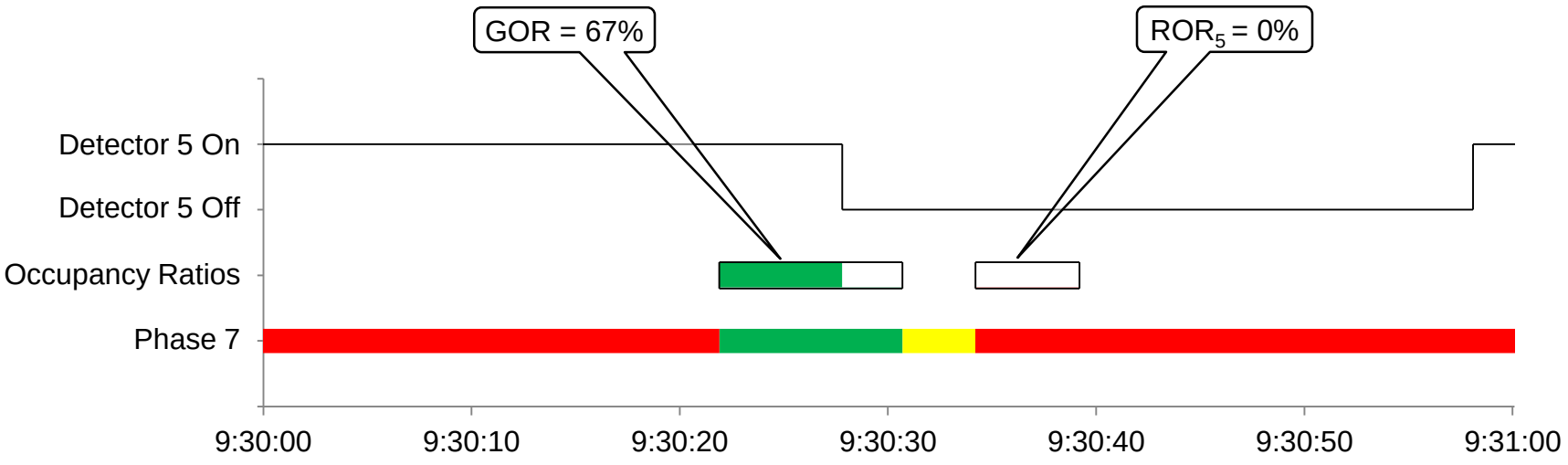


5 Seconds After Start of Red (9:30:41.6)



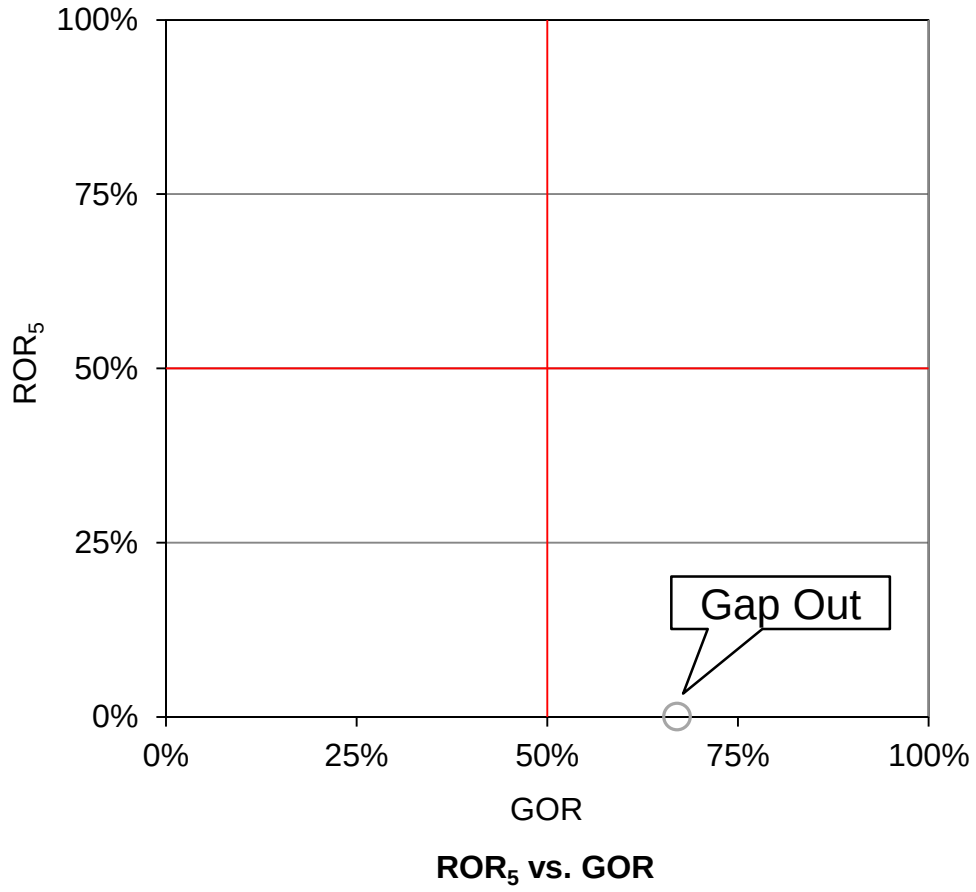
Calculation Illustration of GOR and ROR_5

ROR_5 vs. GOR for an Undersaturated Split (Phase 7)



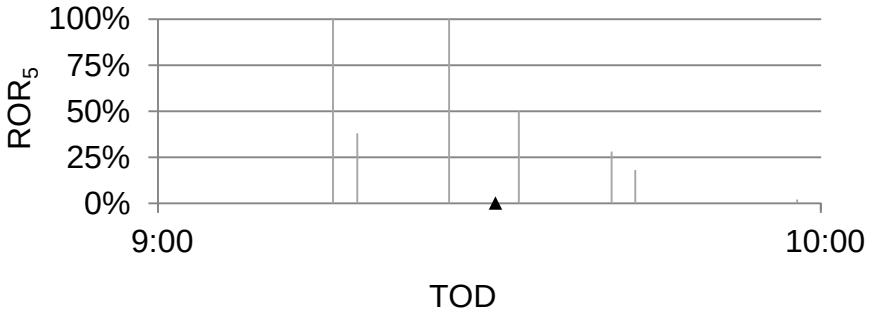
Calculation Illustration of GOR and ROR_5

ROR_5 vs. GOR for an Undersaturated Split (Phase 7)

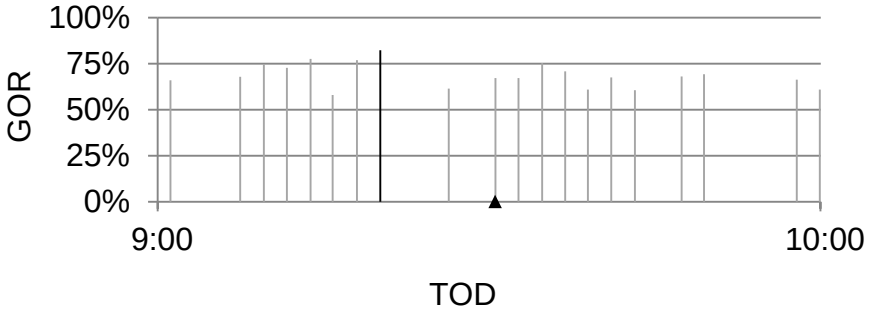


ROR_5 vs. GOR

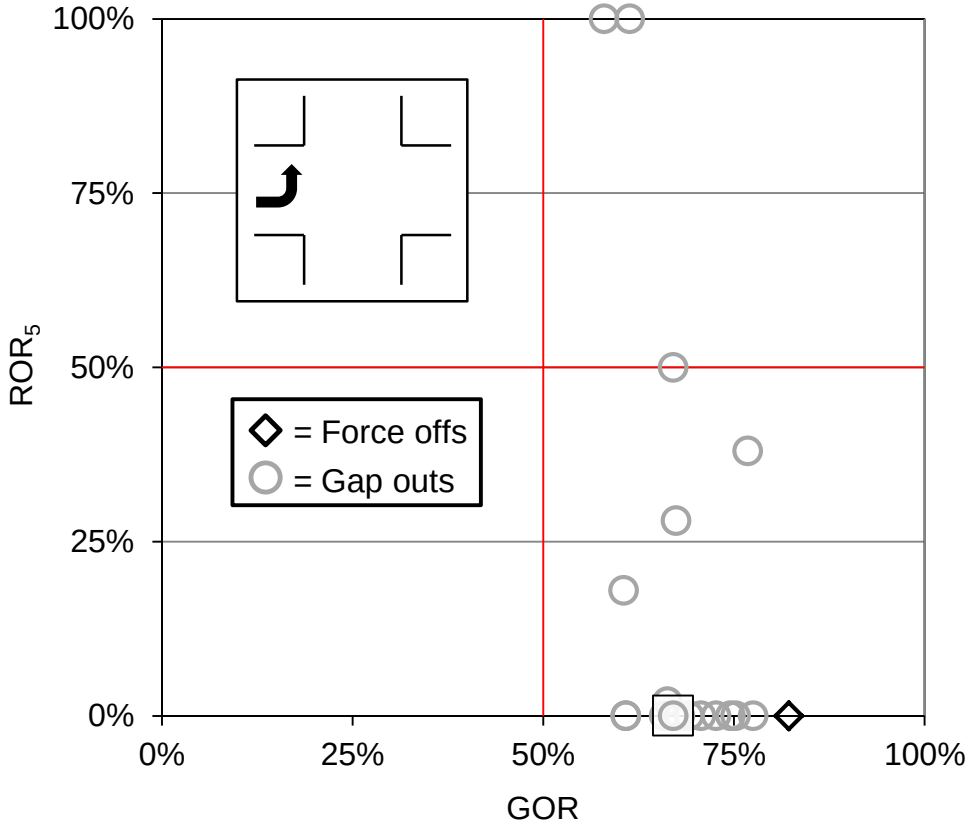
ROR_5 vs. GOR Plot for an Undersaturated Left Turn



ROR_5 vs. TOD (0900-1000)



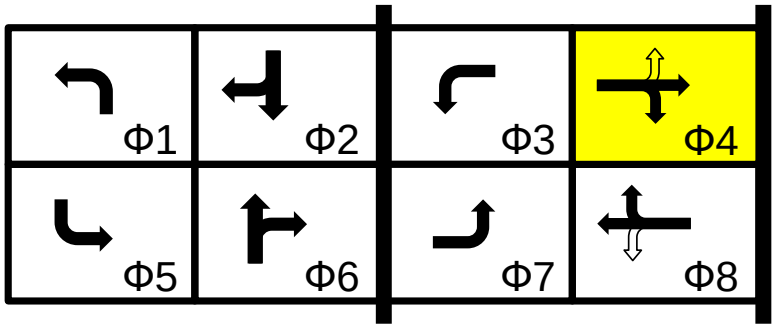
GOR vs. TOD (0900-1000)



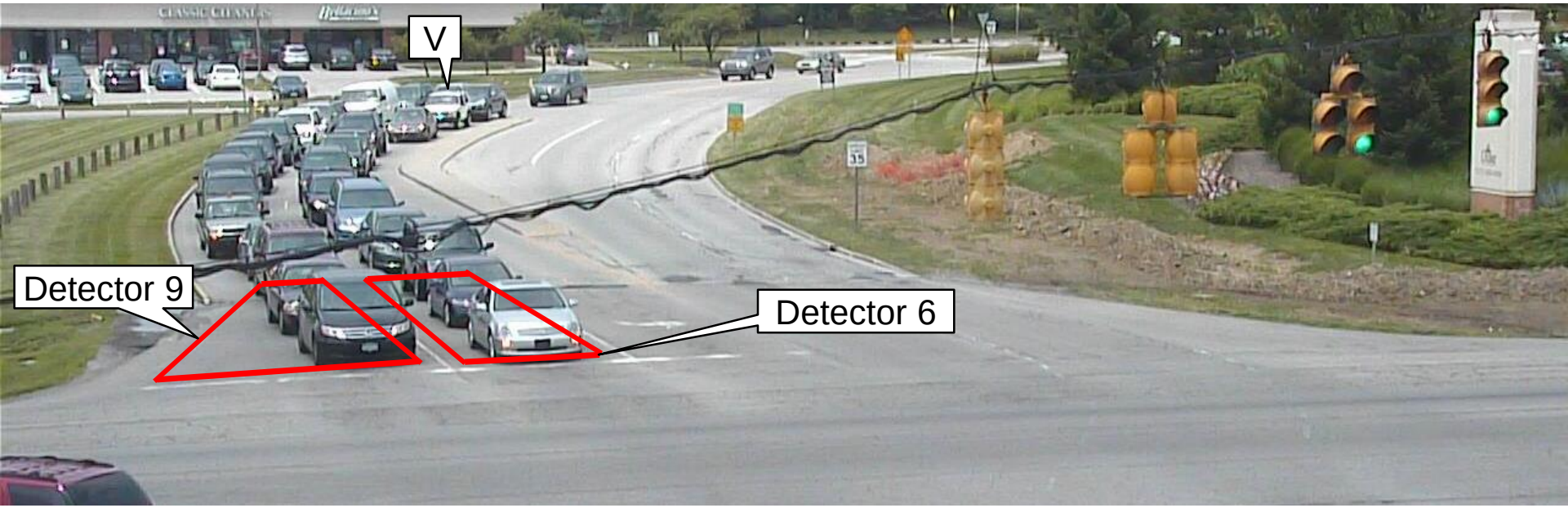
ROR_5 vs. GOR (0900-1000)

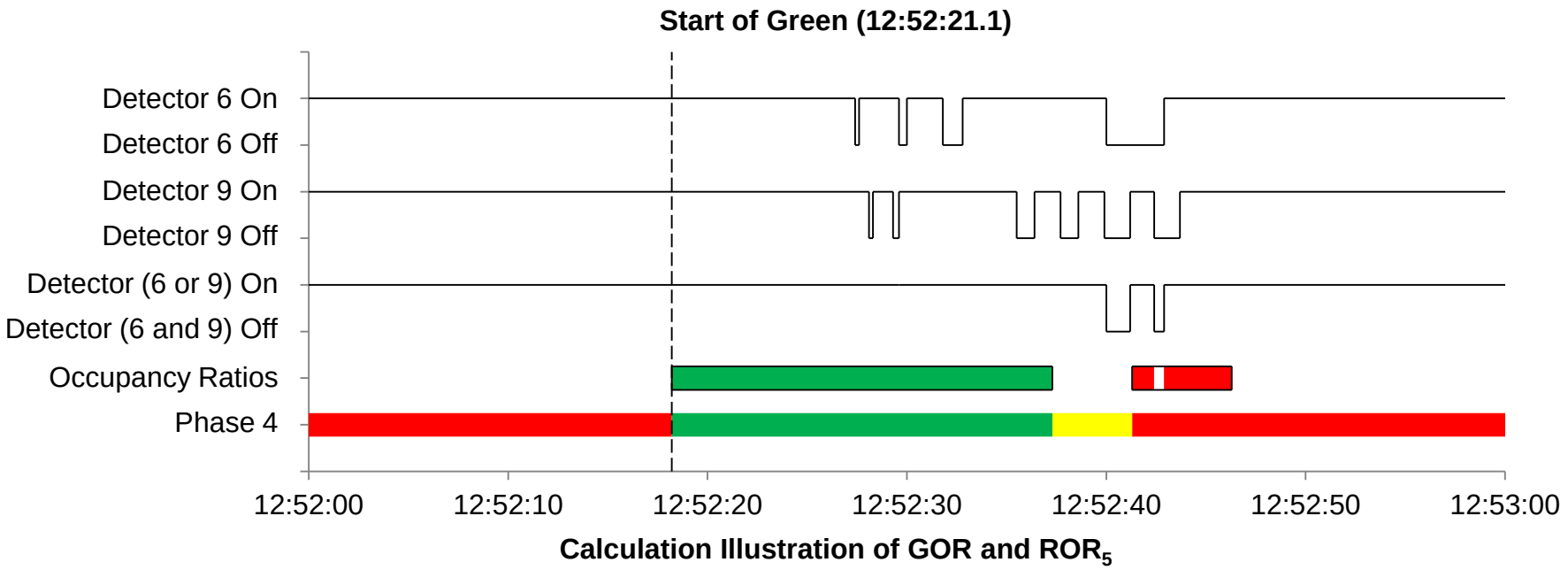
Phase 4 Extension Timer

Extension Timer = 3.0 seconds



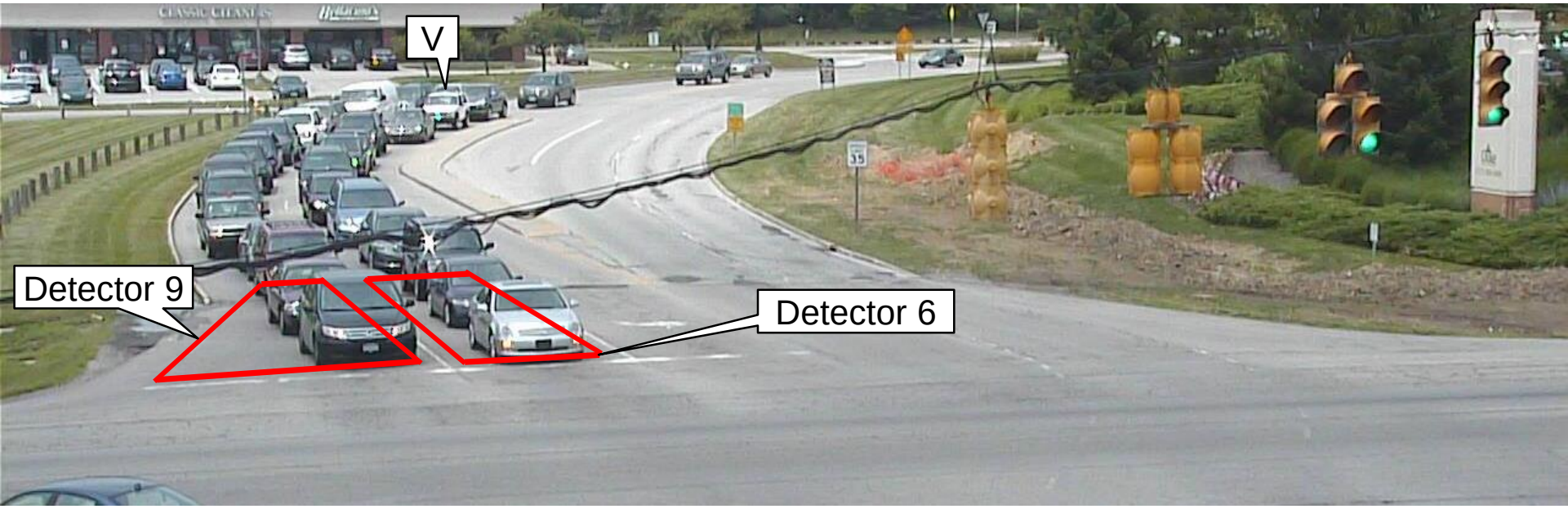
ROR_5 vs. GOR for an Oversaturated Split (Phase 4)

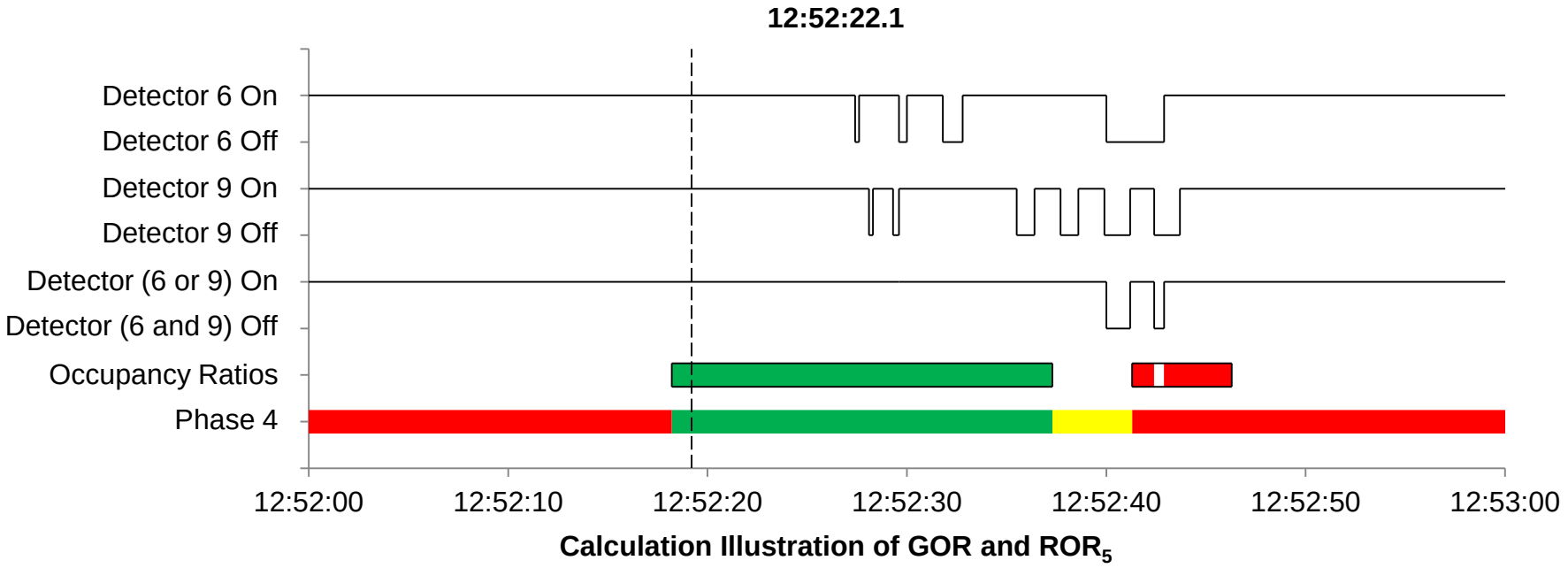




Calculation Illustration of GOR and ROR_5

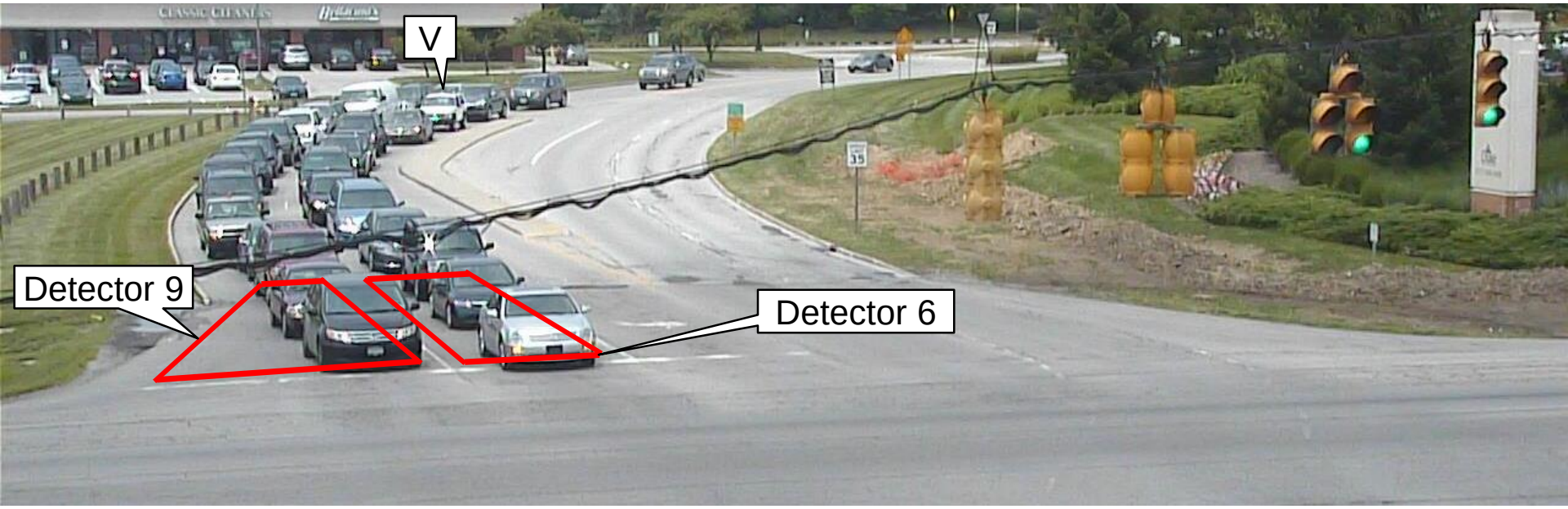
ROR_5 vs. GOR for an Oversaturated Split (Phase 4)

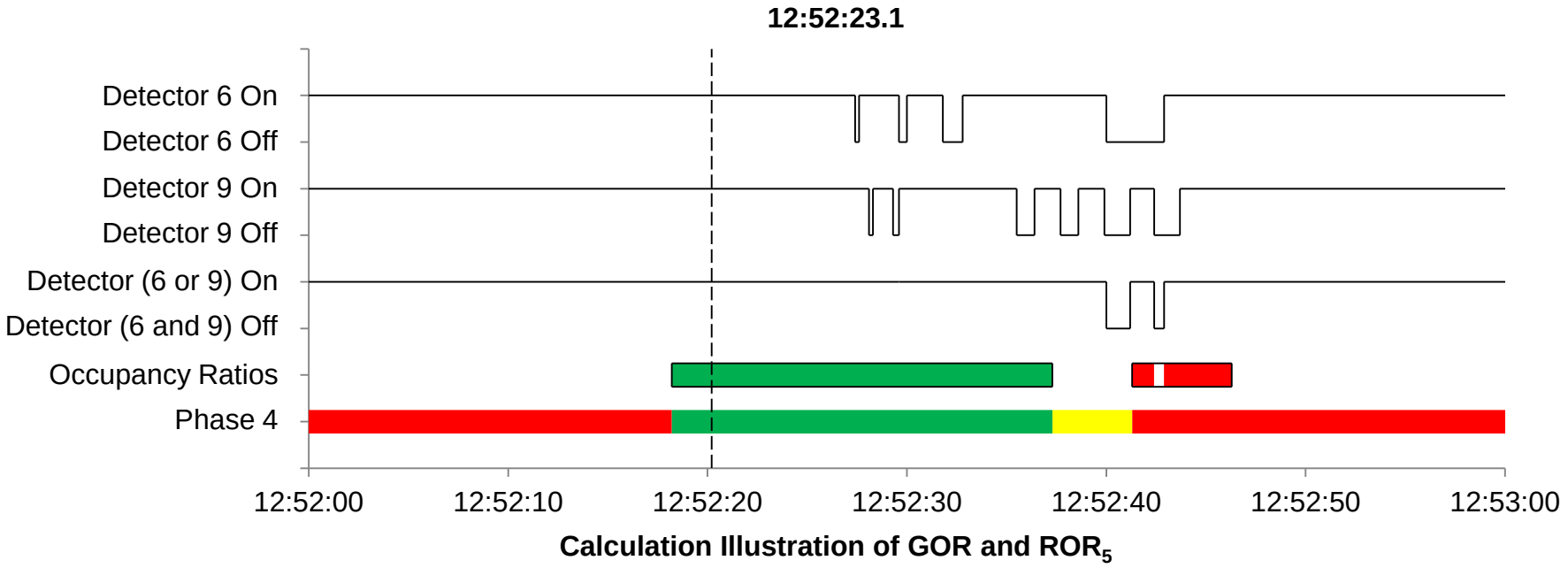




Calculation Illustration of GOR and ROR_5

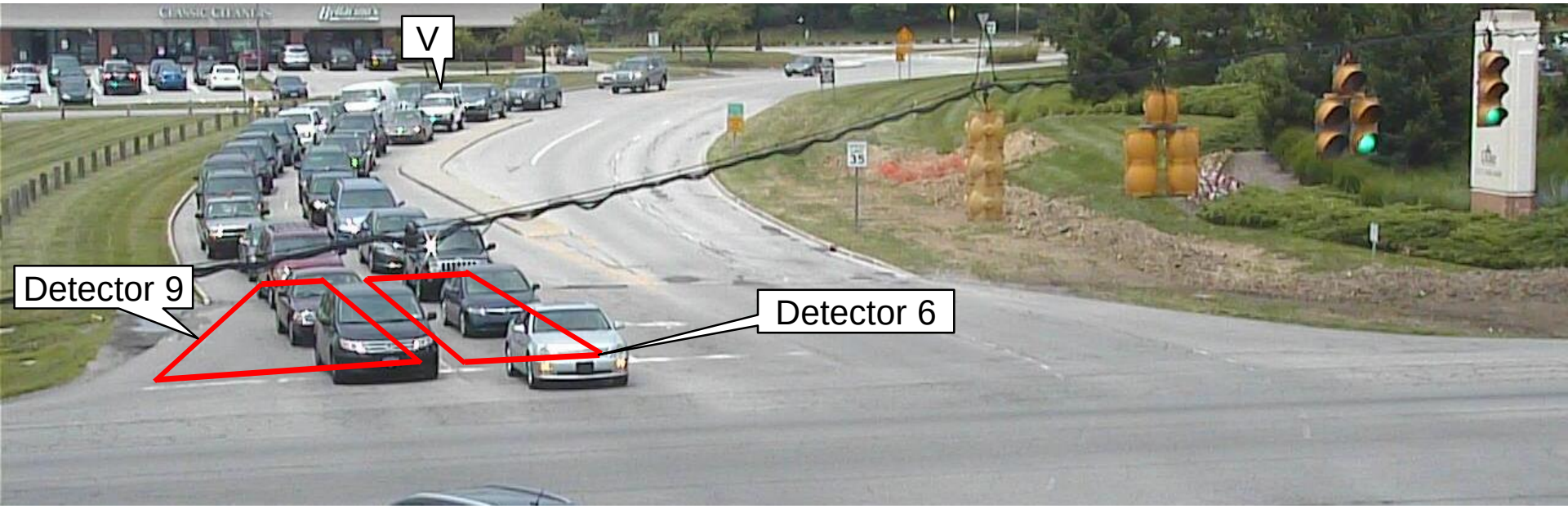
ROR_5 vs. GOR for an Oversaturated Split (Phase 4)

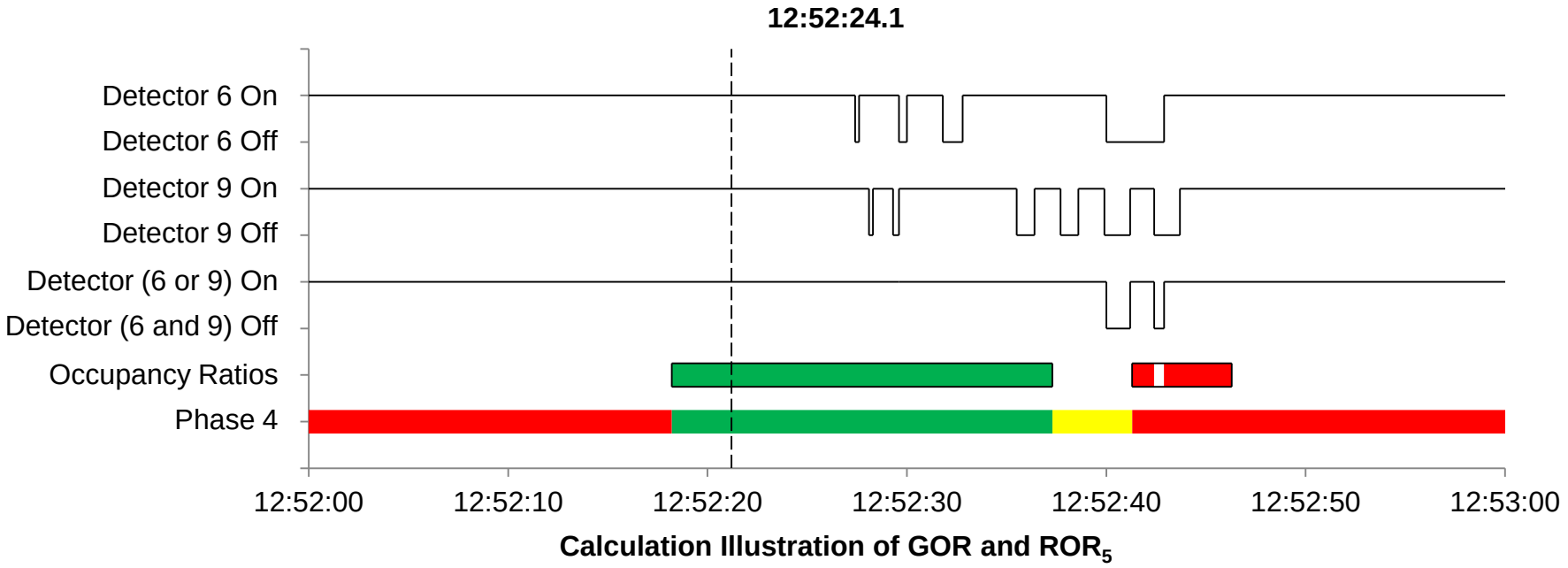




Calculation Illustration of GOR and ROR_5

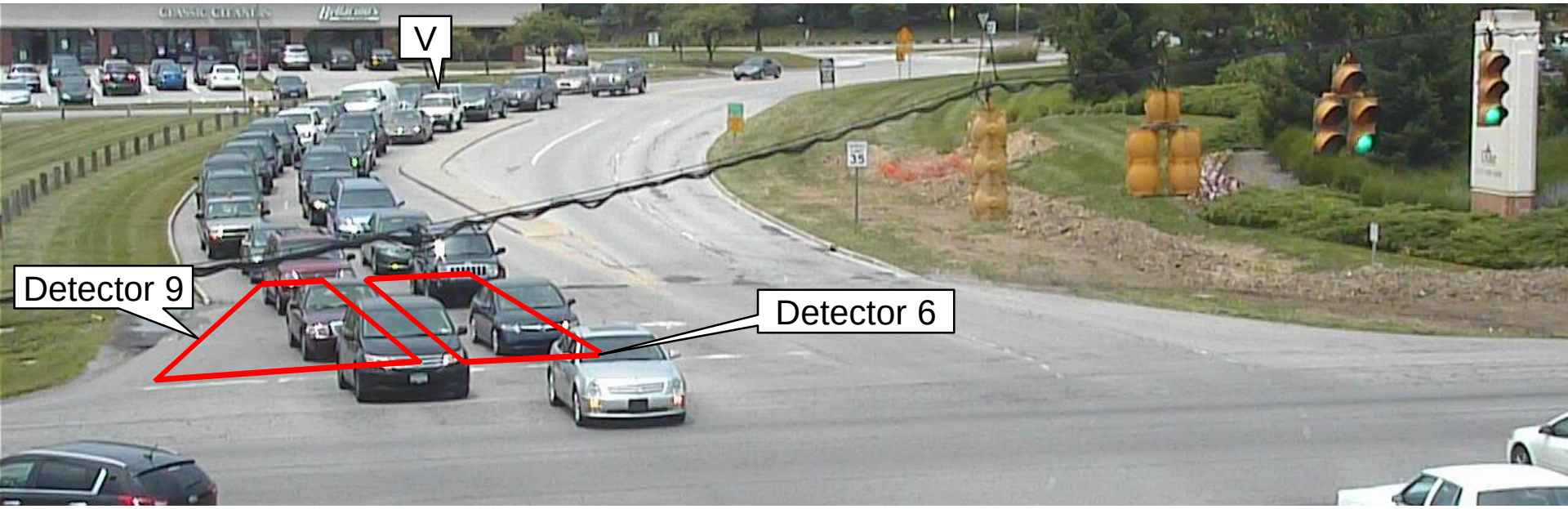
ROR_5 vs. GOR for an Oversaturated Split (Phase 4)

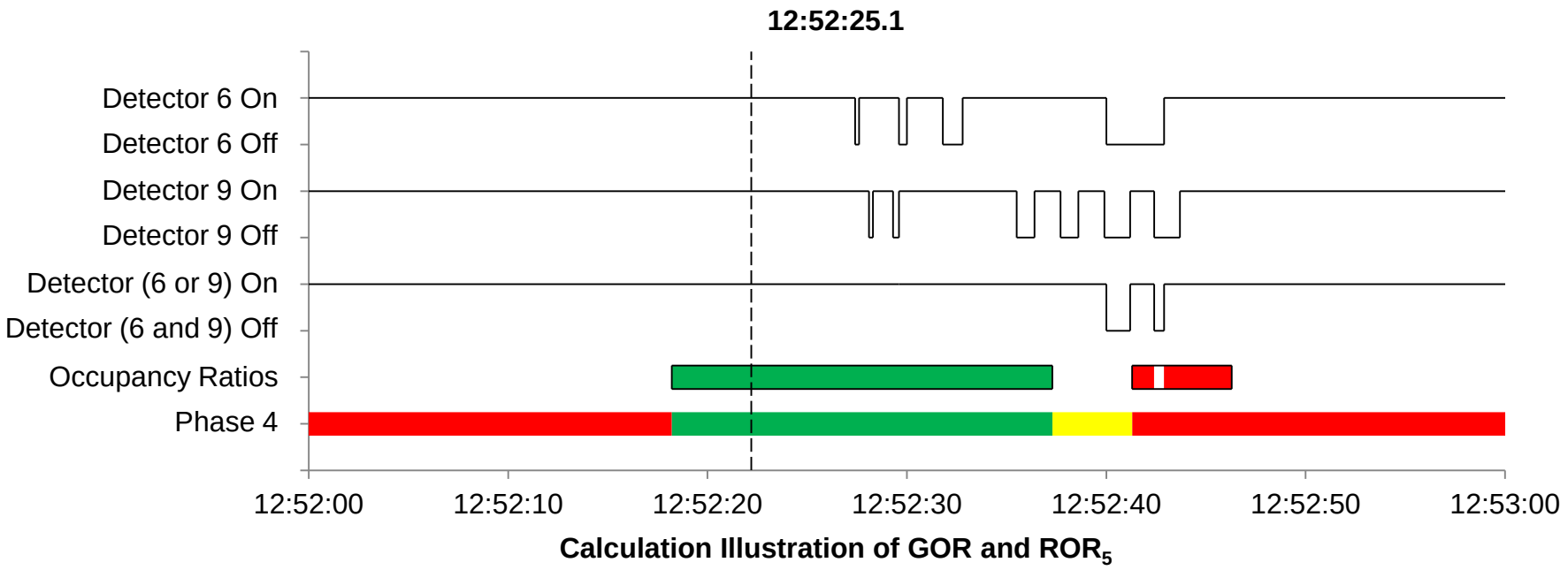




Calculation Illustration of GOR and ROR_5

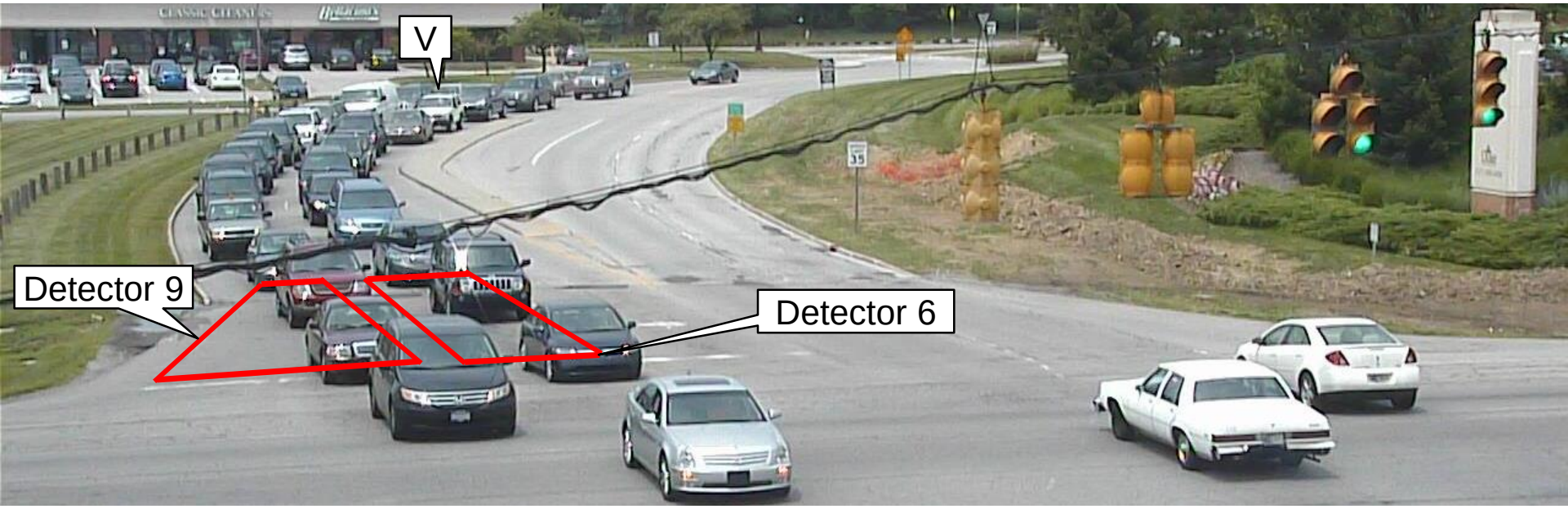
ROR_5 vs. GOR for an Oversaturated Split (Phase 4)

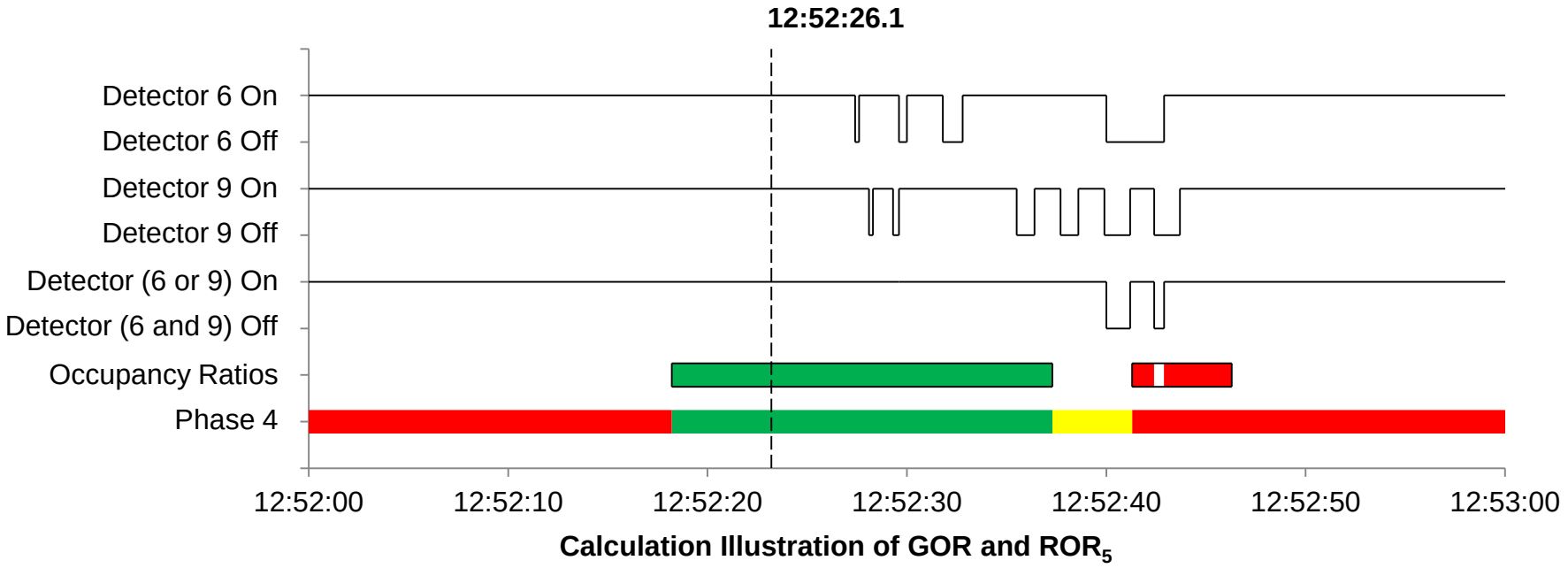




Calculation Illustration of GOR and ROR_5

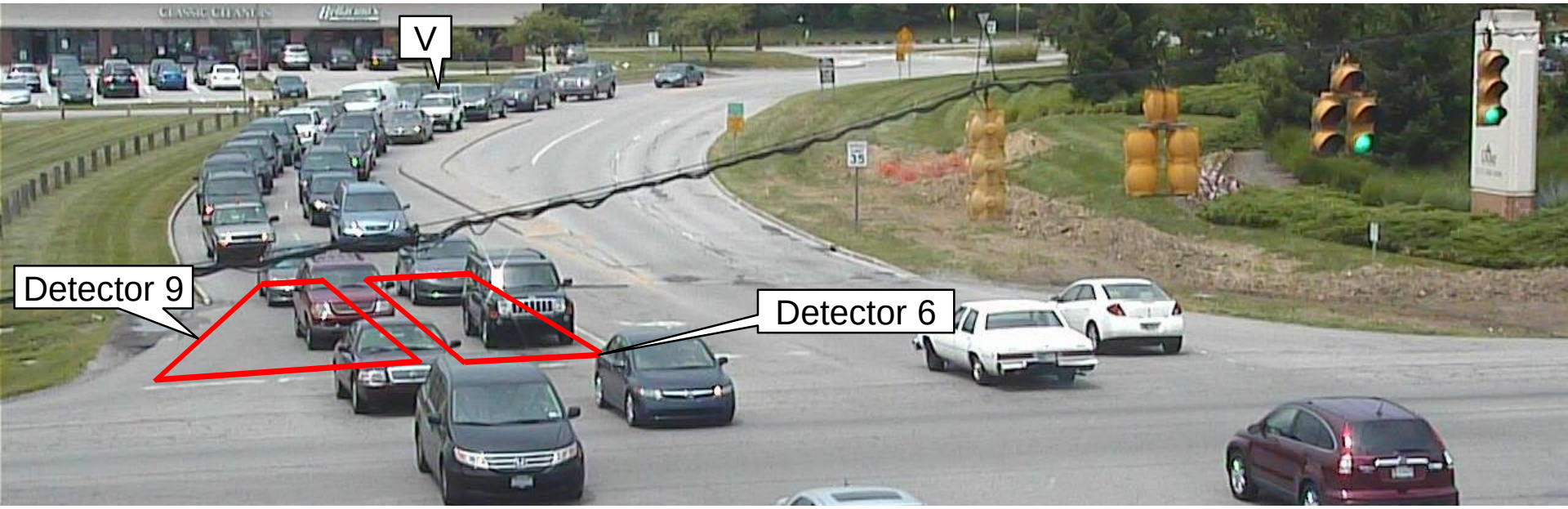
ROR_5 vs. GOR for an Oversaturated Split (Phase 4)

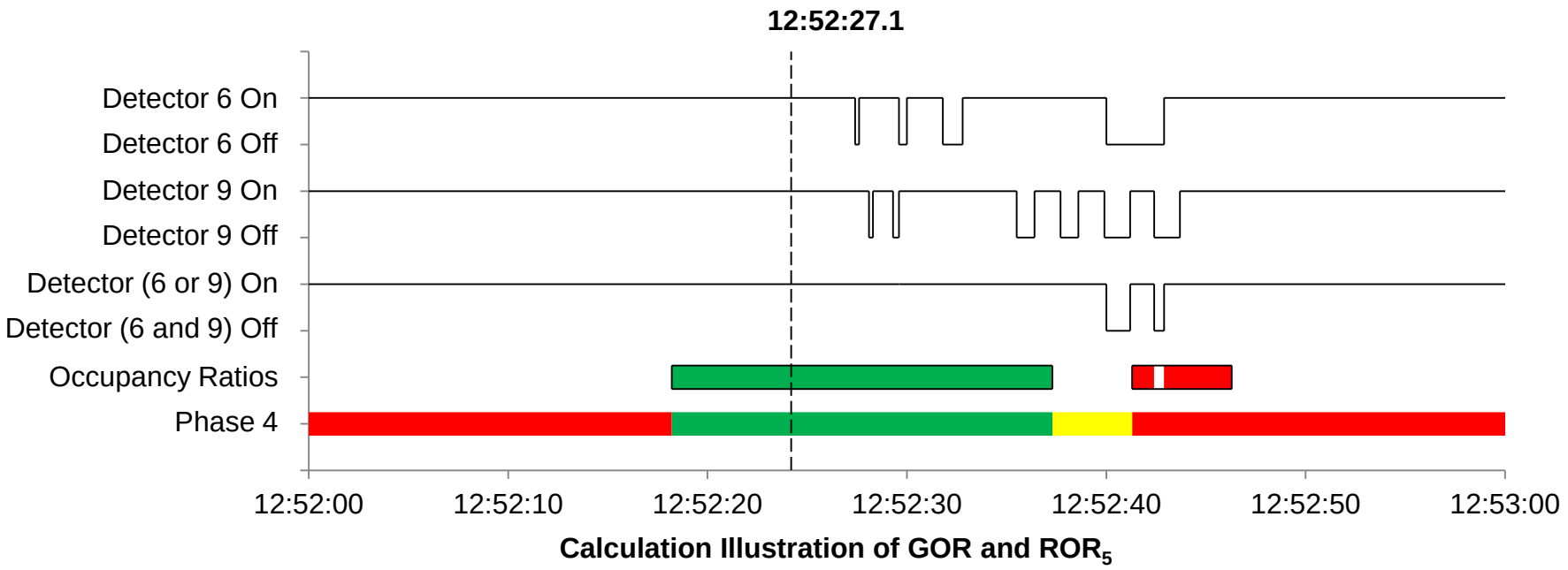




Calculation Illustration of GOR and ROR_5

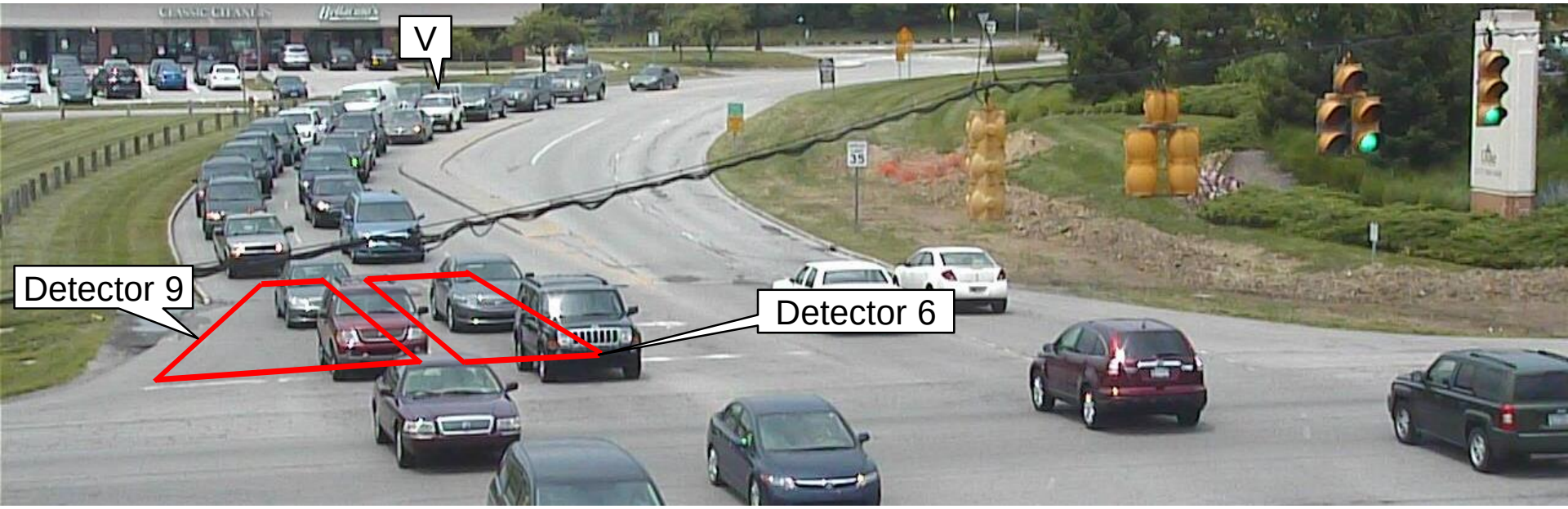
ROR_5 vs. GOR for an Oversaturated Split (Phase 4)

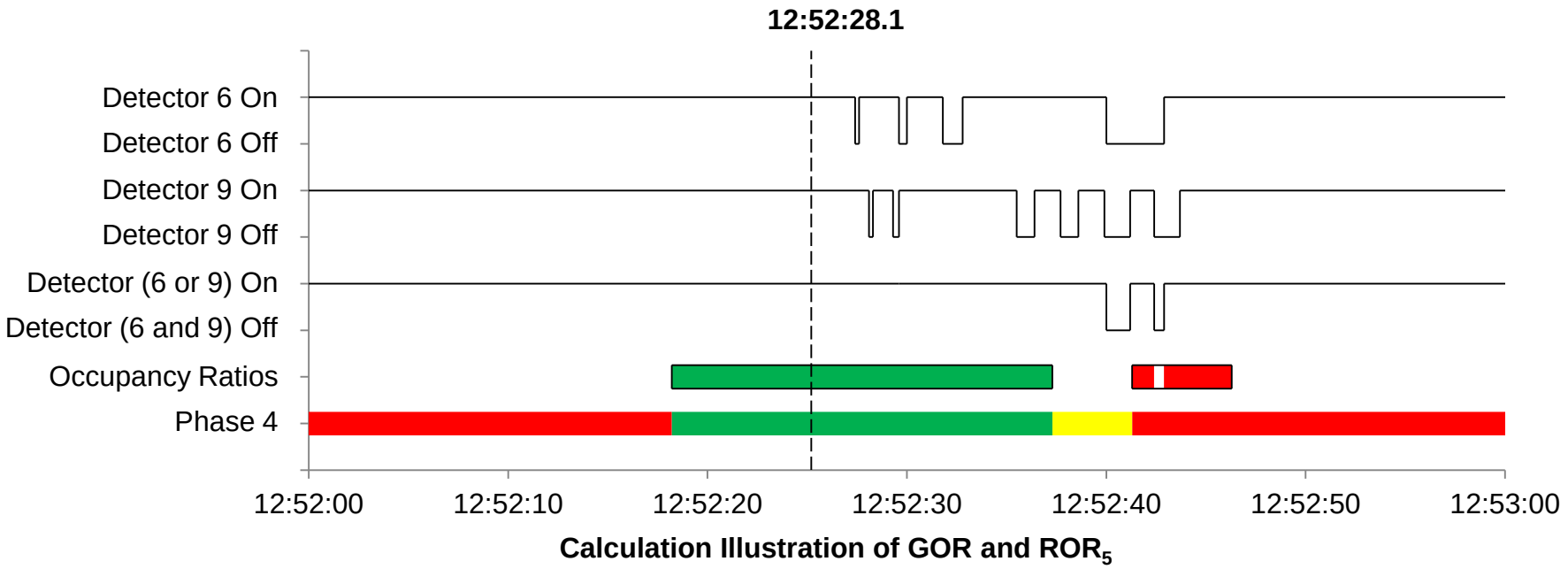




Calculation Illustration of GOR and ROR_5

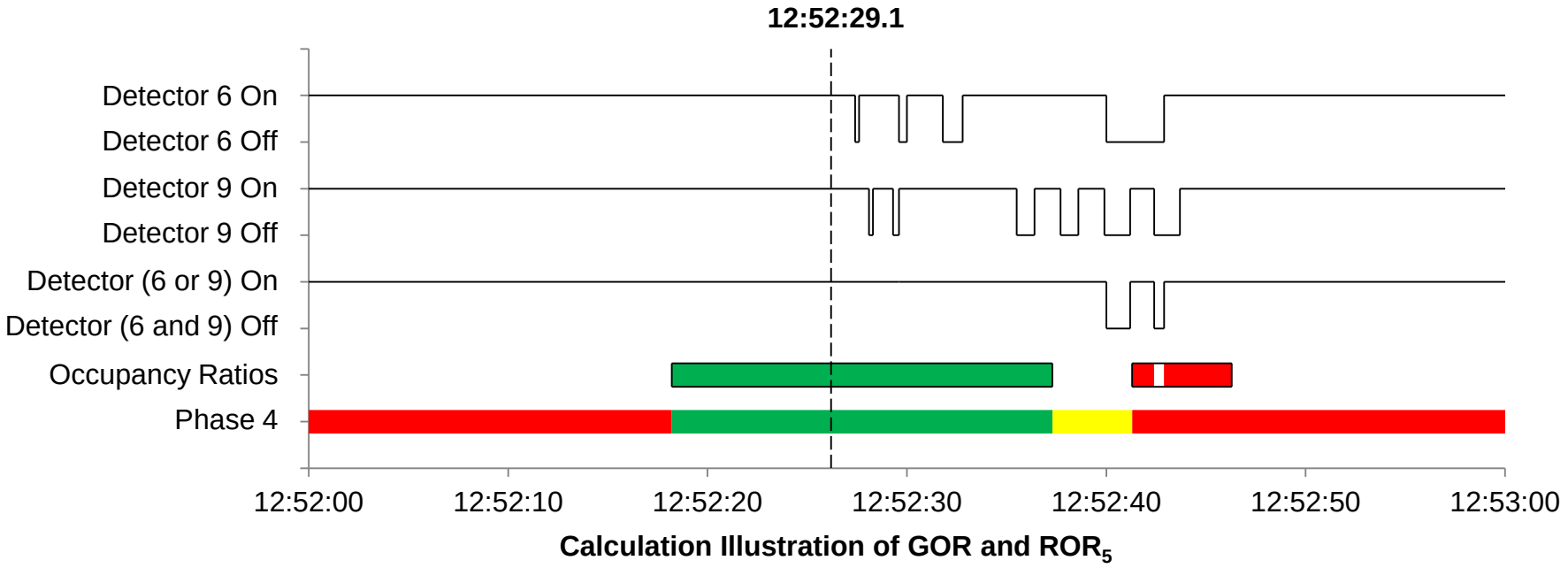
ROR_5 vs. GOR for an Oversaturated Split (Phase 4)





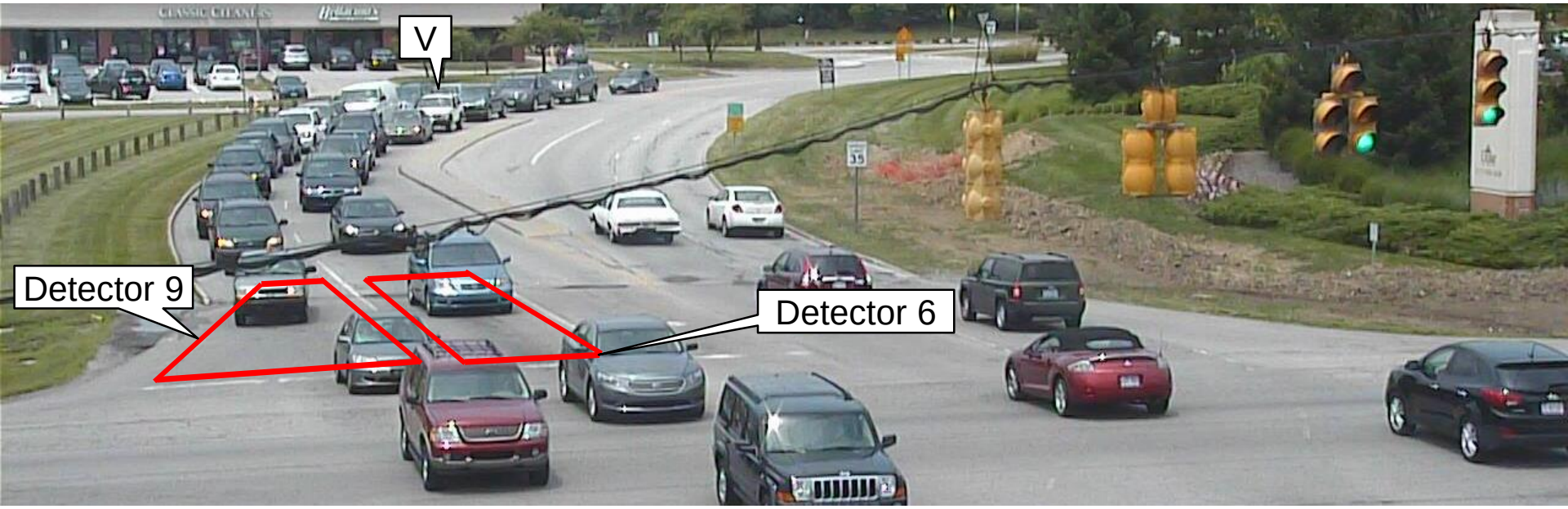
Calculation Illustration of GOR and ROR_5

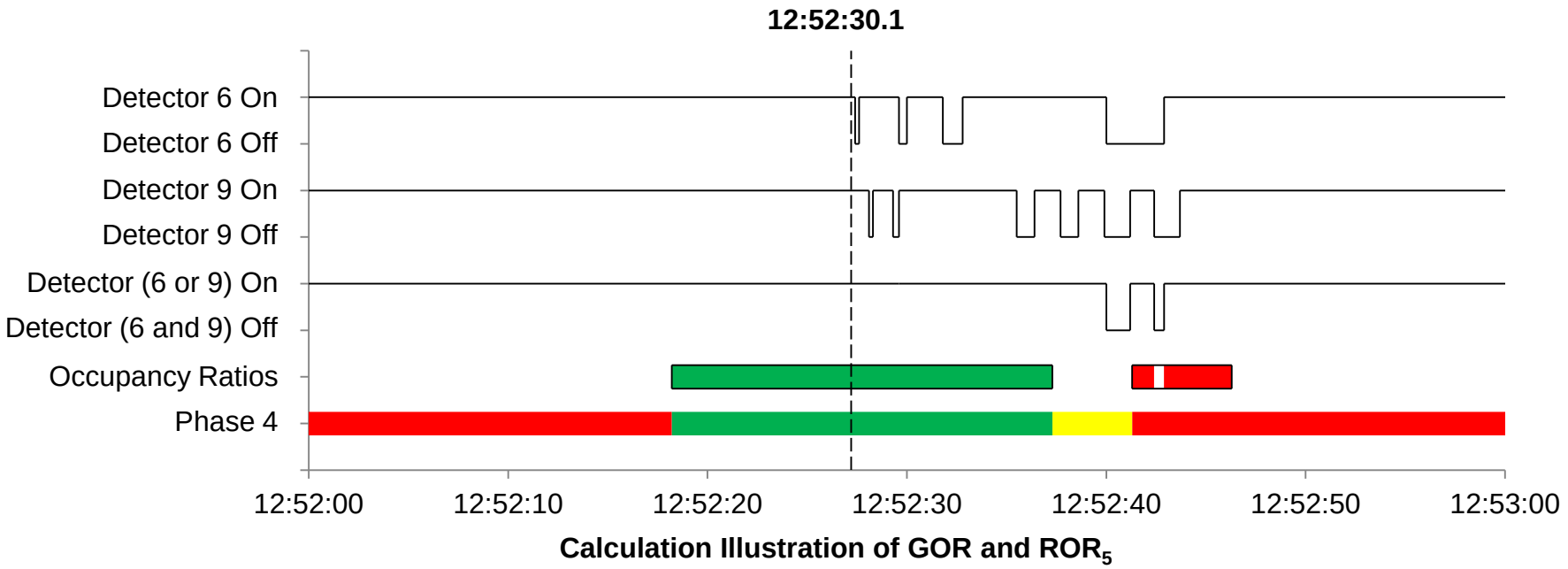
ROR_5 vs. GOR for an Oversaturated Split (Phase 4)



Calculation Illustration of GOR and ROR_5

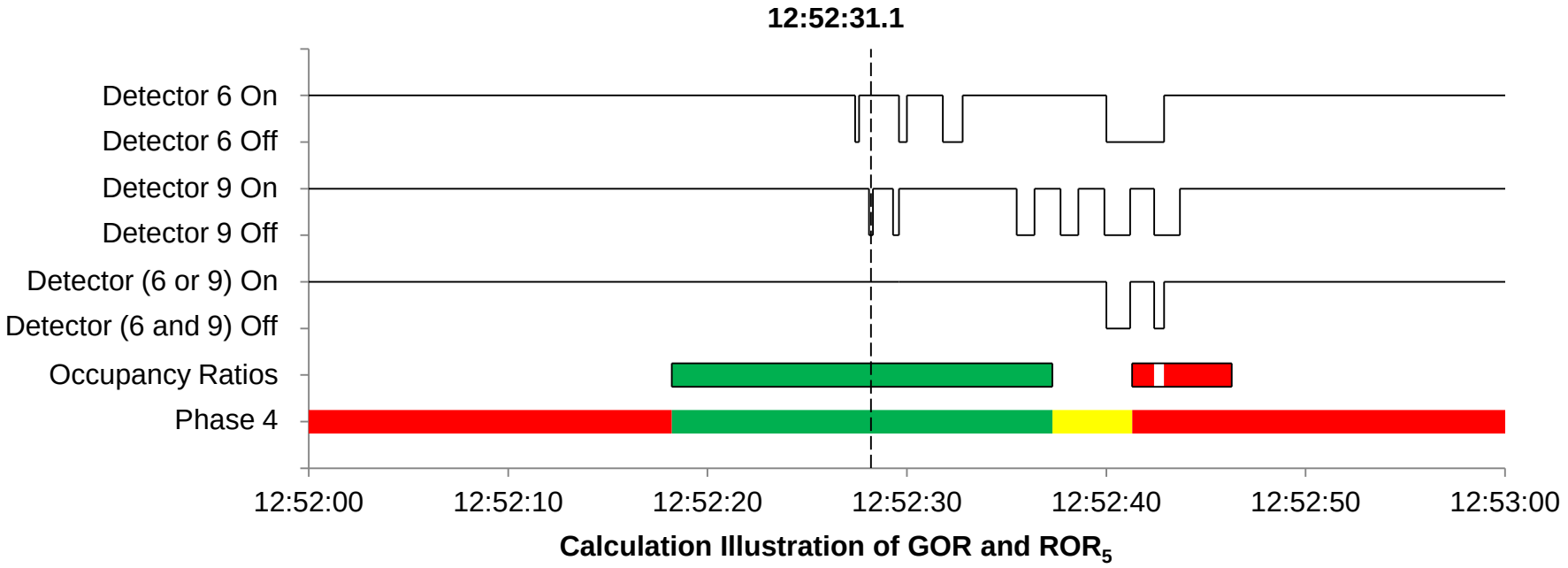
ROR_5 vs. GOR for an Oversaturated Split (Phase 4)





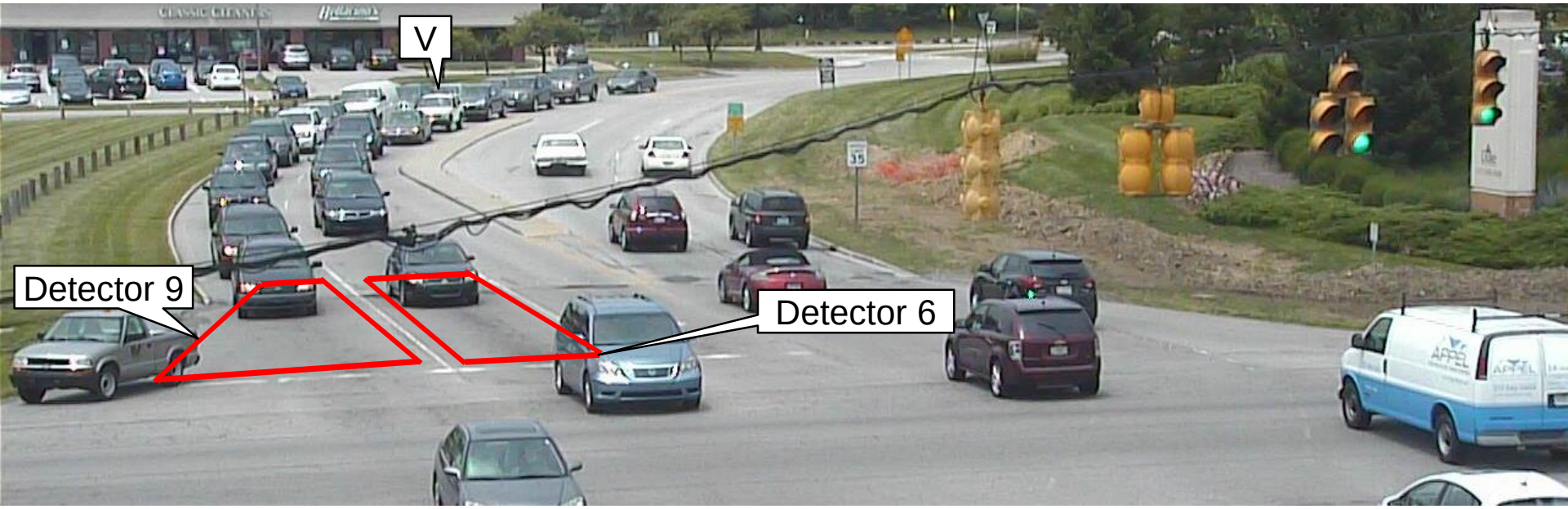
Calculation Illustration of GOR and ROR_5

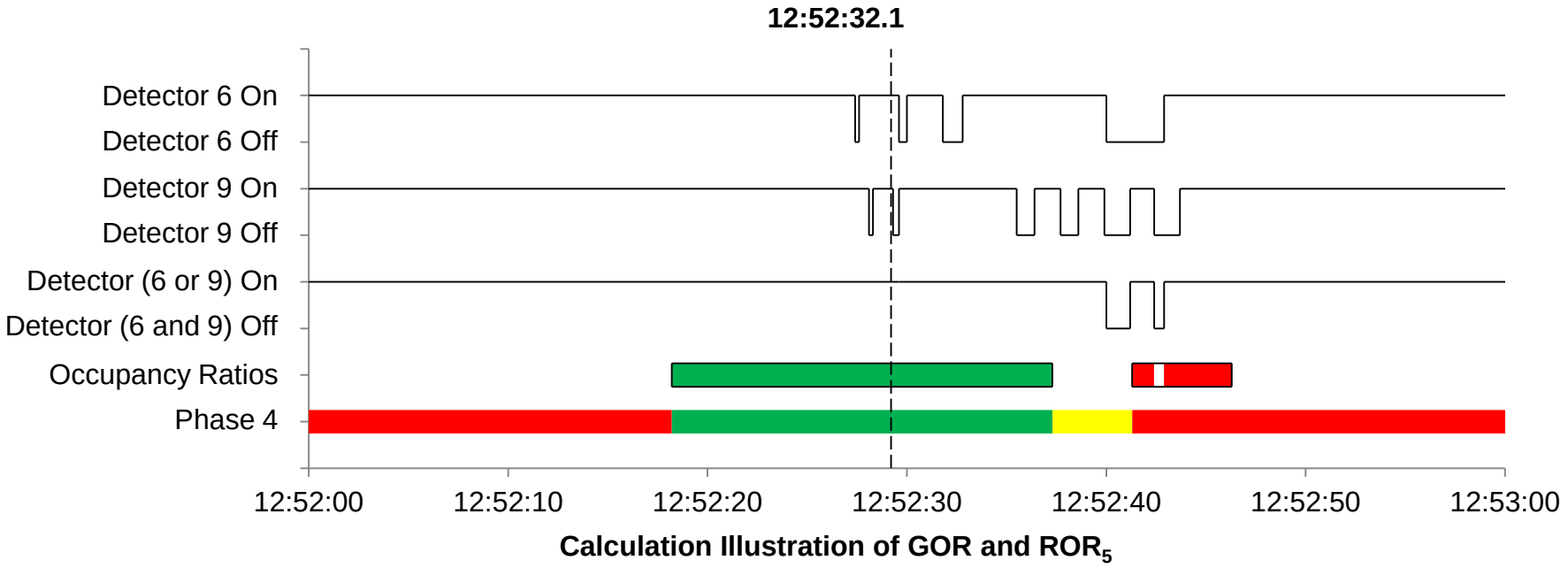
ROR_5 vs. GOR for an Oversaturated Split (Phase 4)



Calculation Illustration of GOR and ROR_5

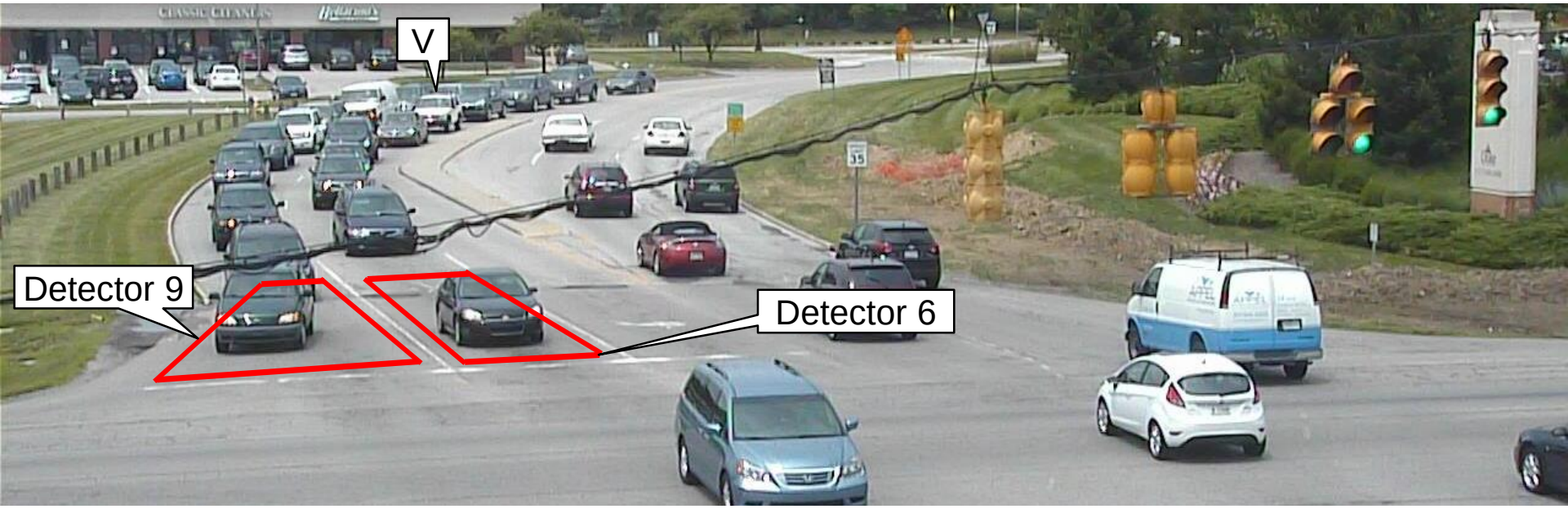
ROR_5 vs. GOR for an Oversaturated Split (Phase 4)

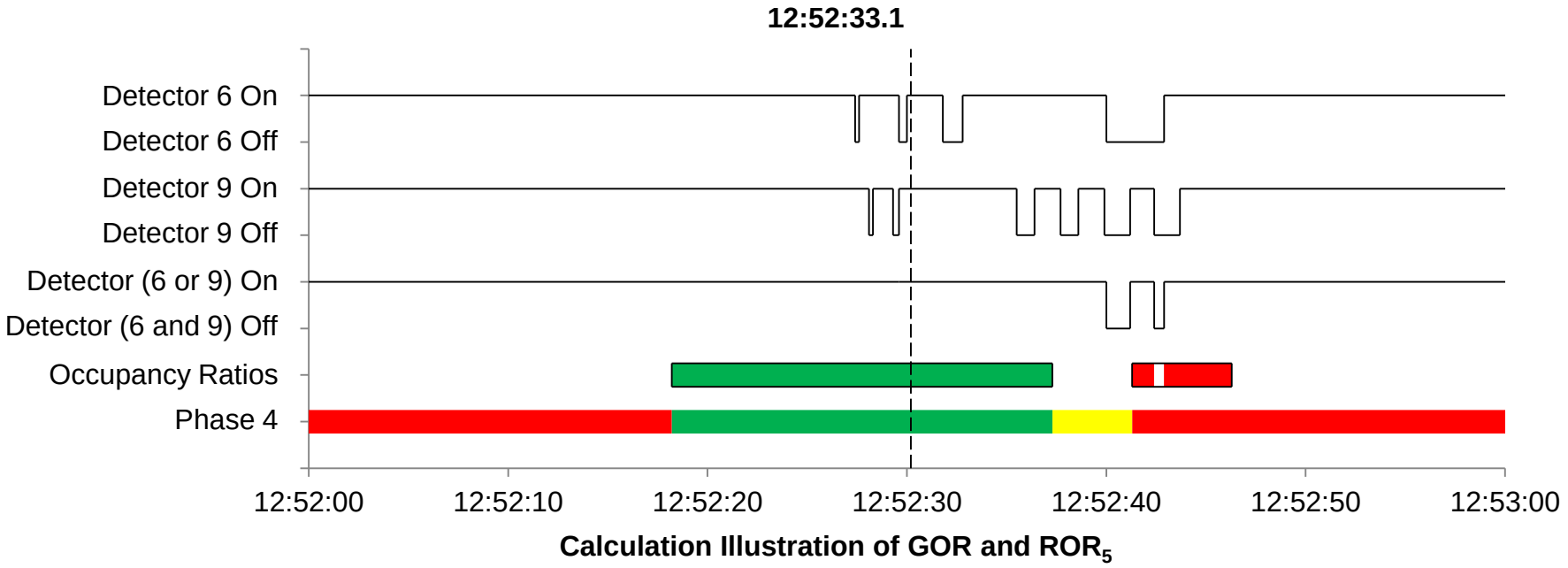




Calculation Illustration of GOR and ROR_5

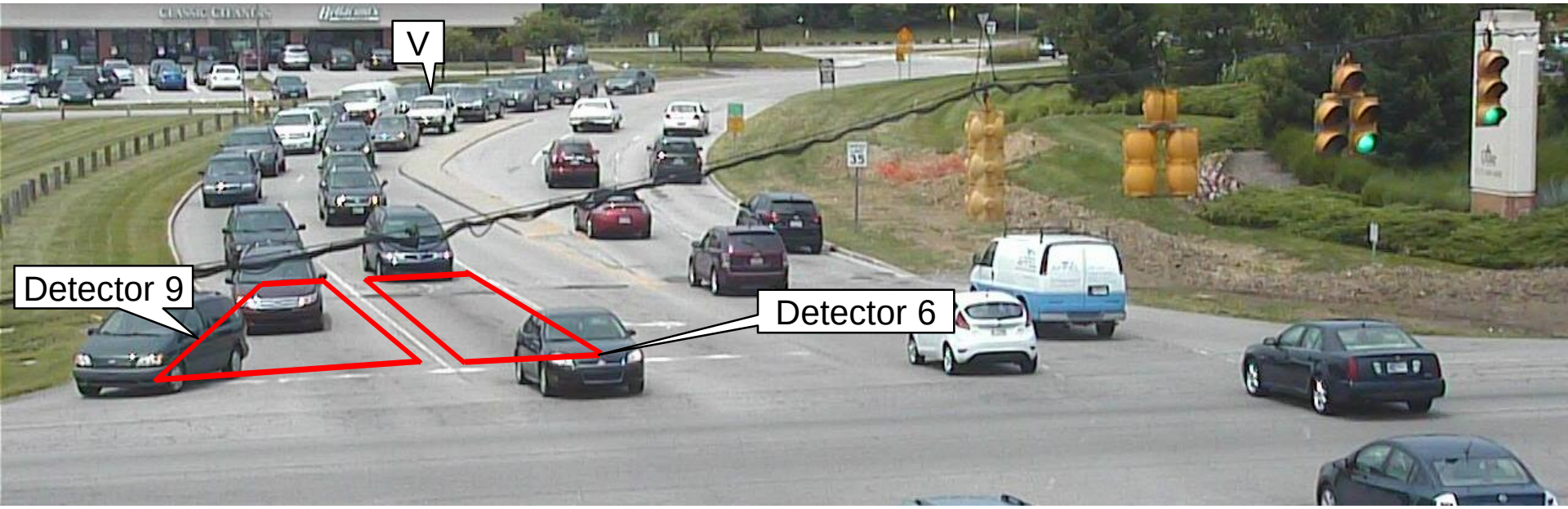
ROR_5 vs. GOR for an Oversaturated Split (Phase 4)

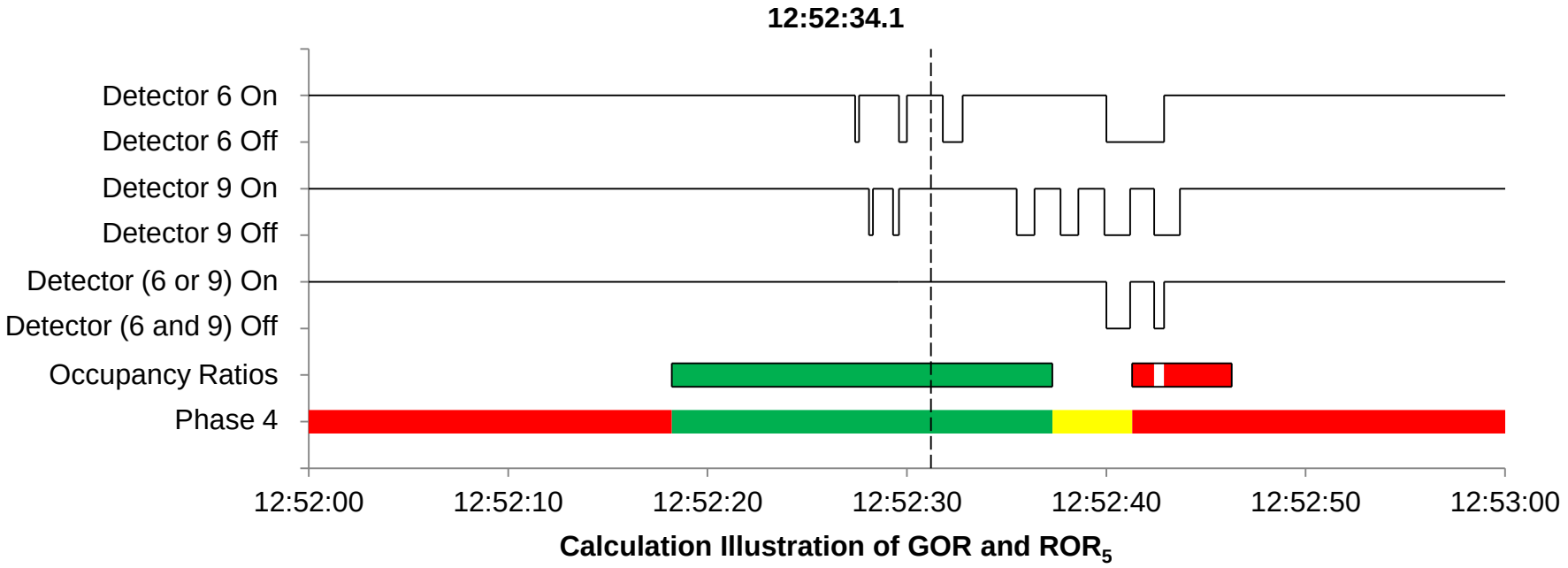




Calculation Illustration of GOR and ROR_5

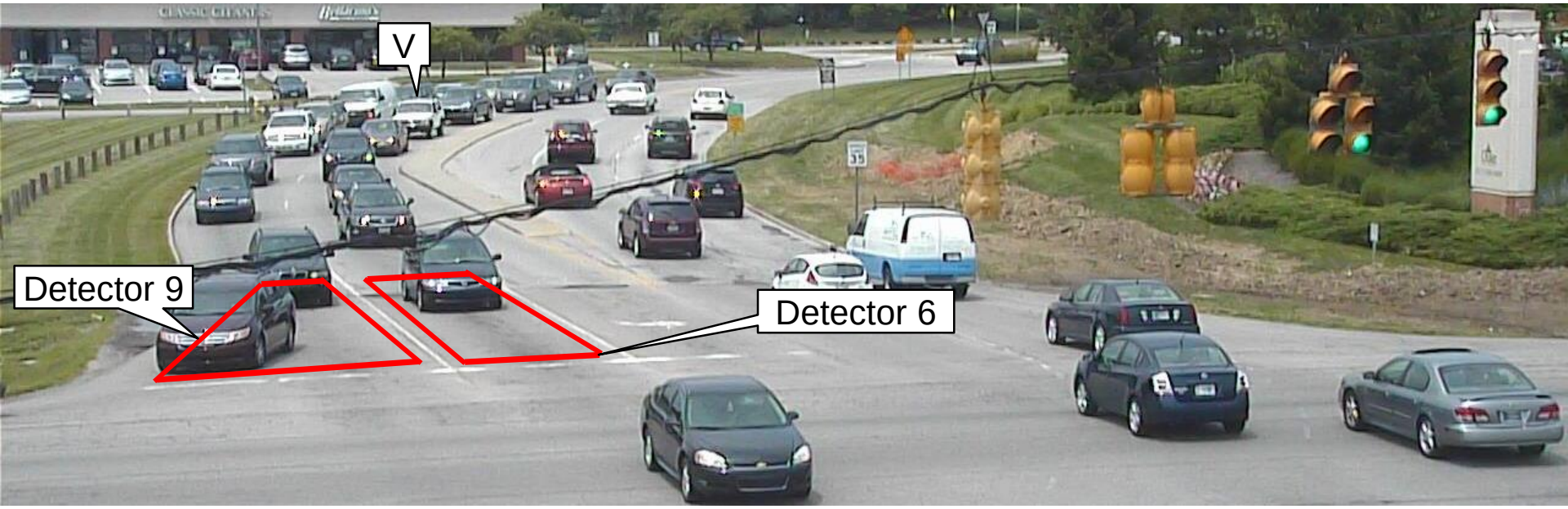
ROR_5 vs. GOR for an Oversaturated Split (Phase 4)

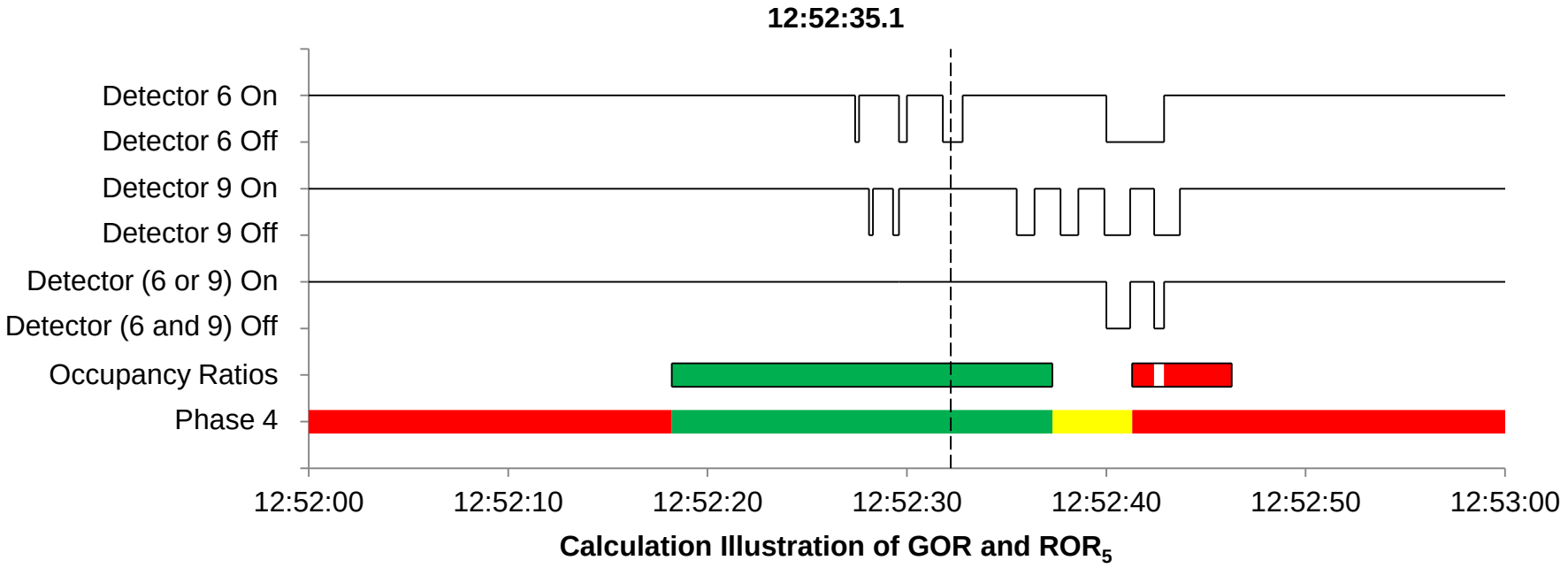




Calculation Illustration of GOR and ROR_5

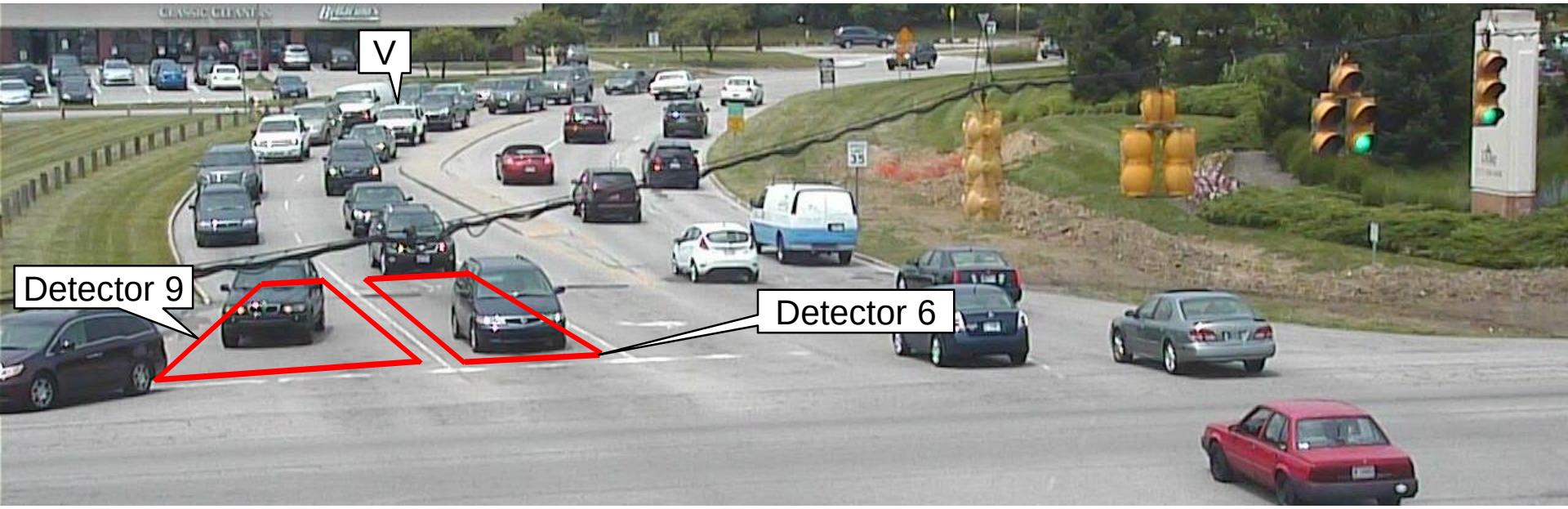
ROR_5 vs. GOR for an Oversaturated Split (Phase 4)

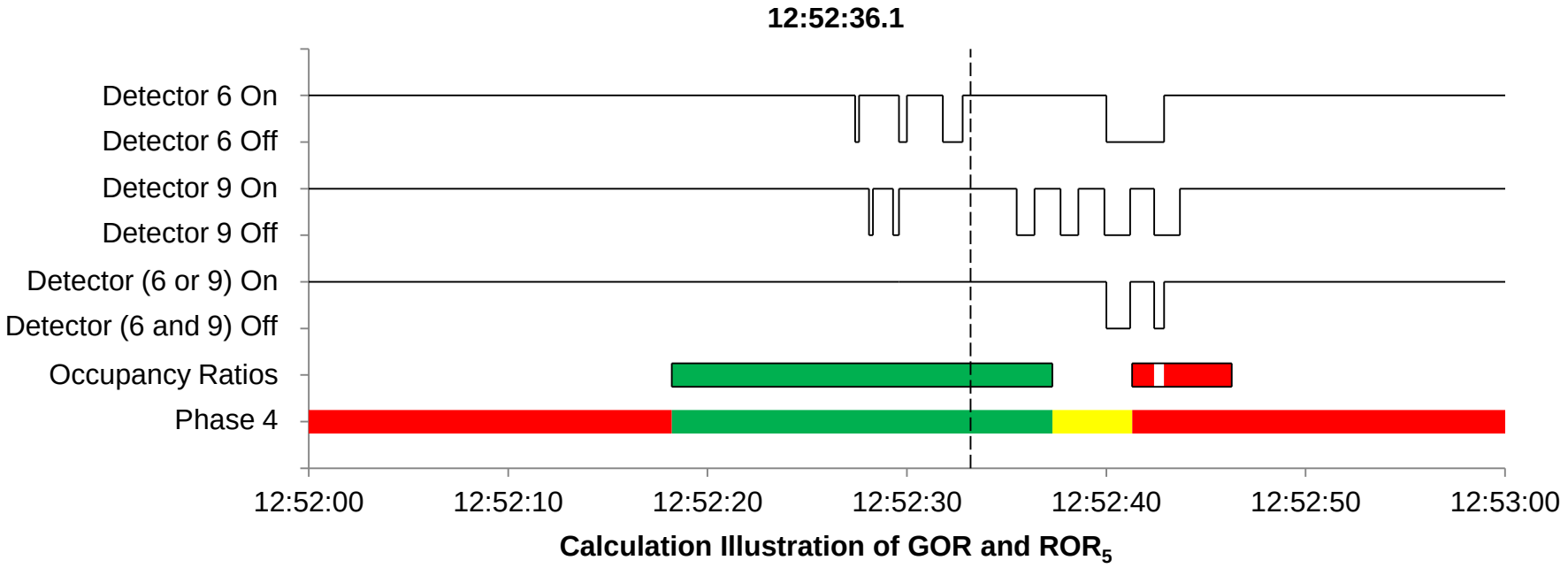




Calculation Illustration of GOR and ROR_5

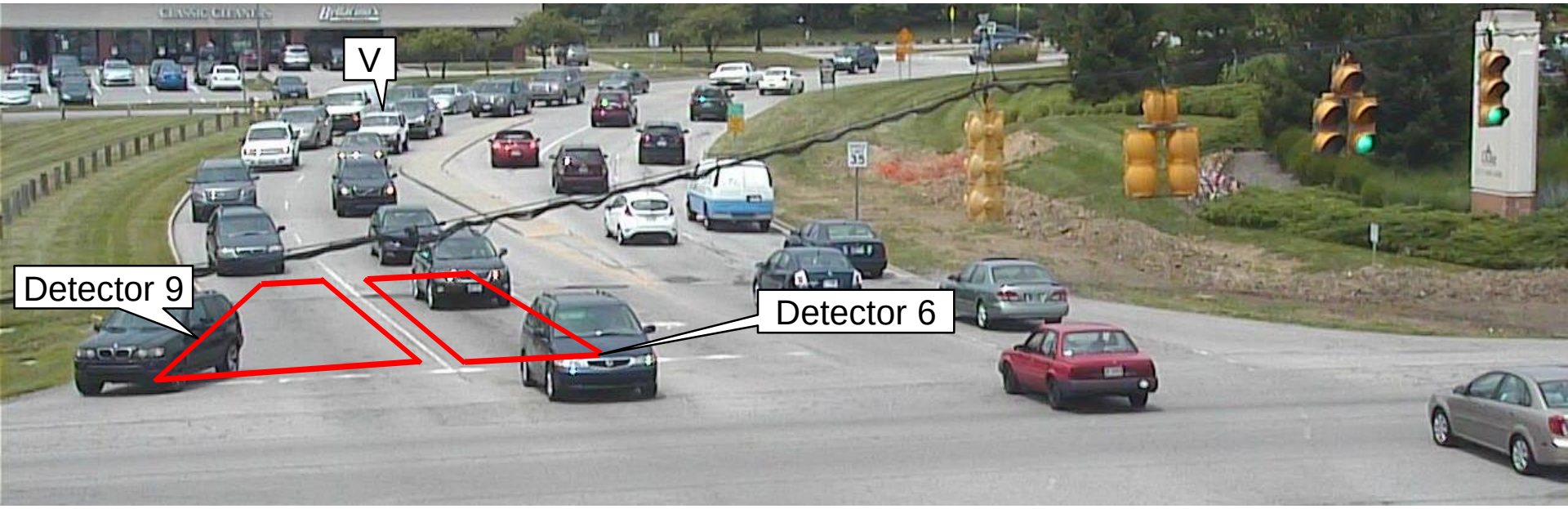
ROR_5 vs. GOR for an Oversaturated Split (Phase 4)

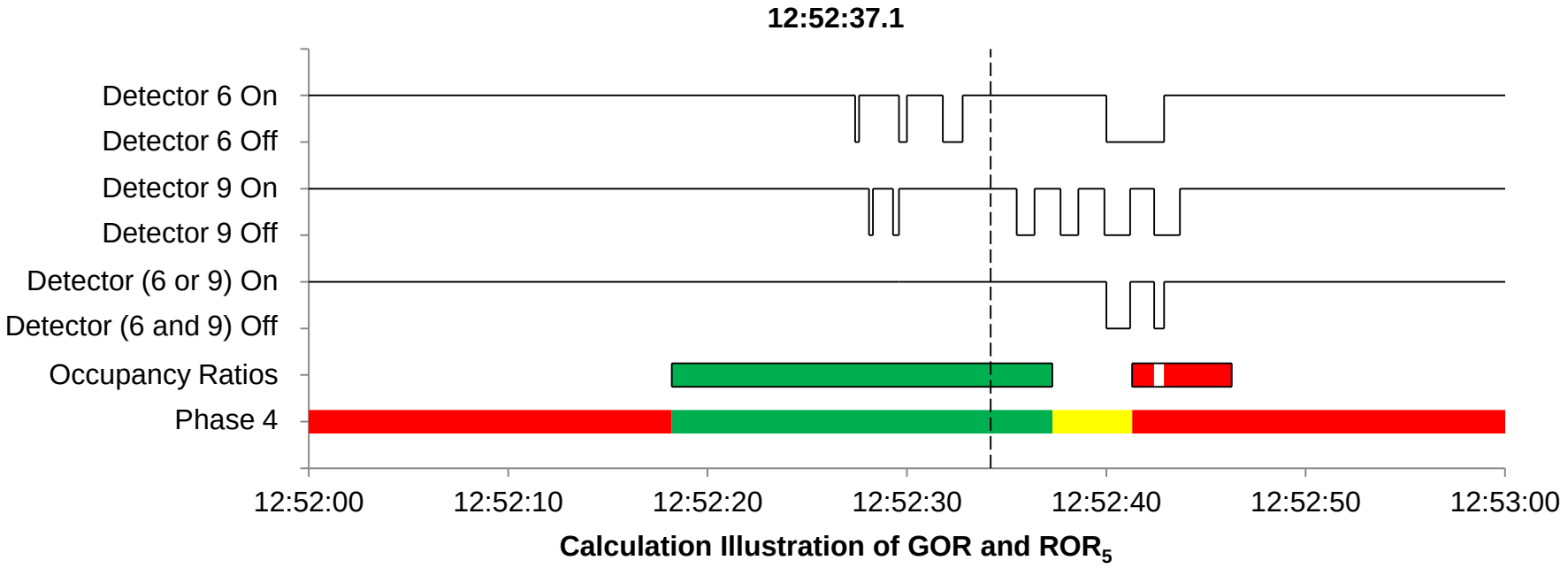




Calculation Illustration of GOR and ROR_5

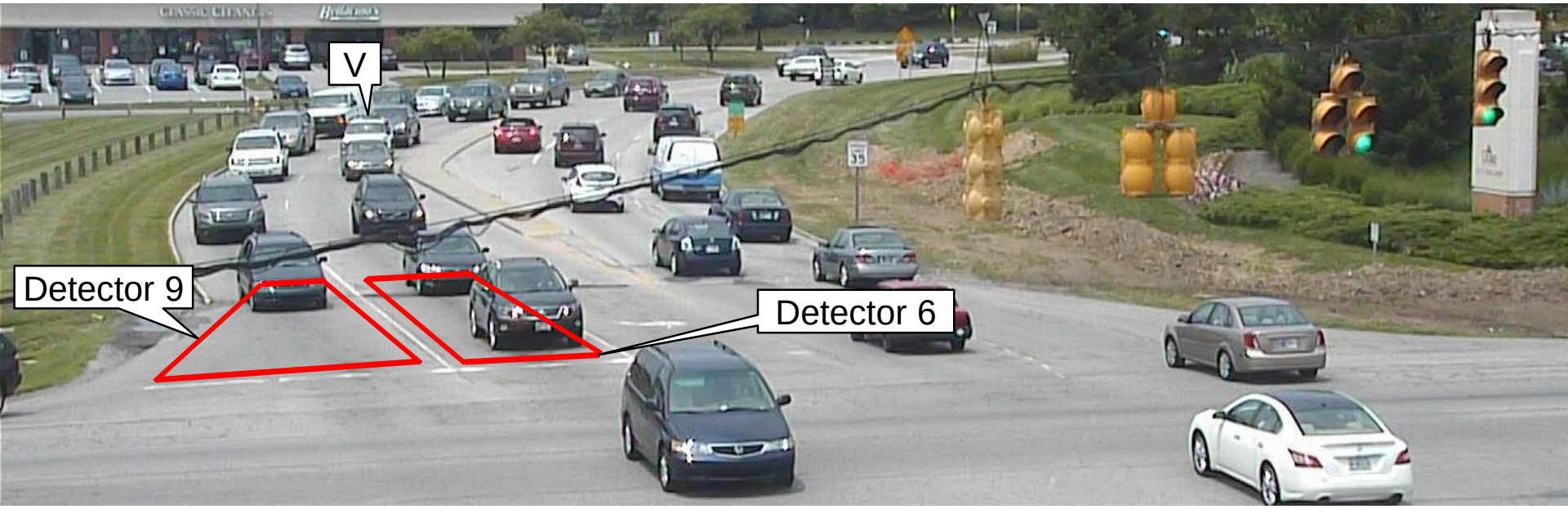
ROR_5 vs. GOR for an Oversaturated Split (Phase 4)

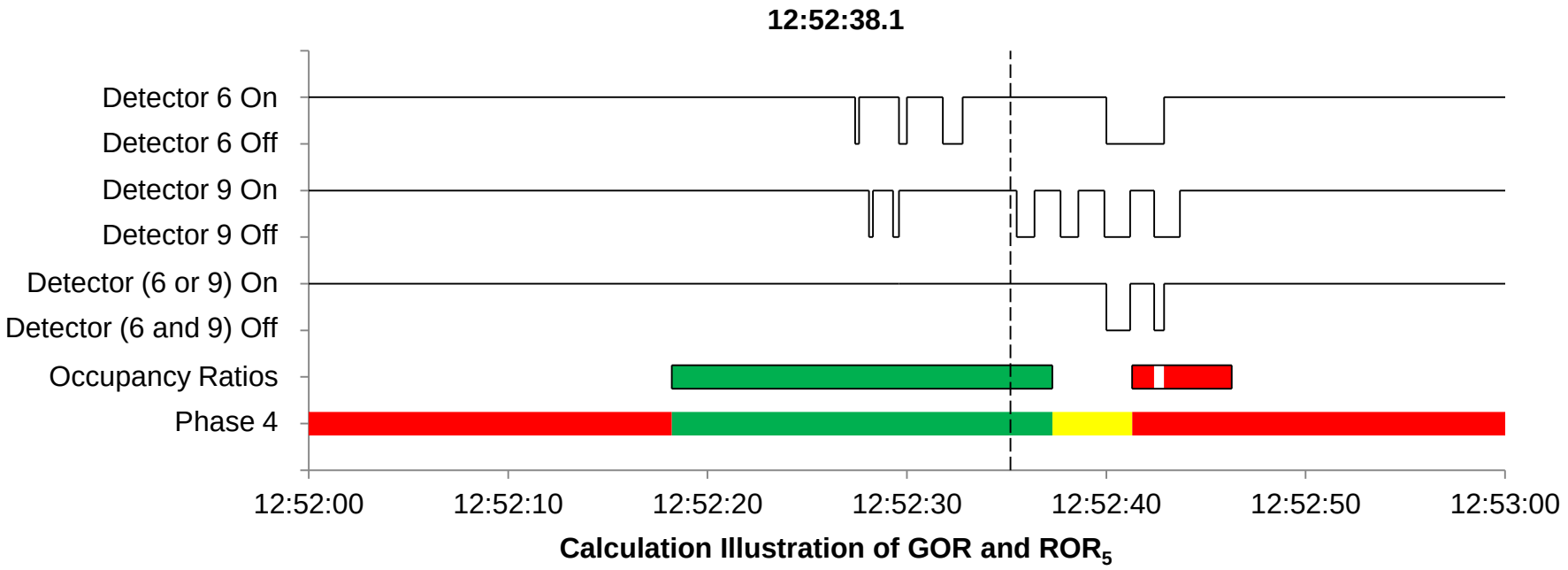




Calculation Illustration of GOR and ROR_5

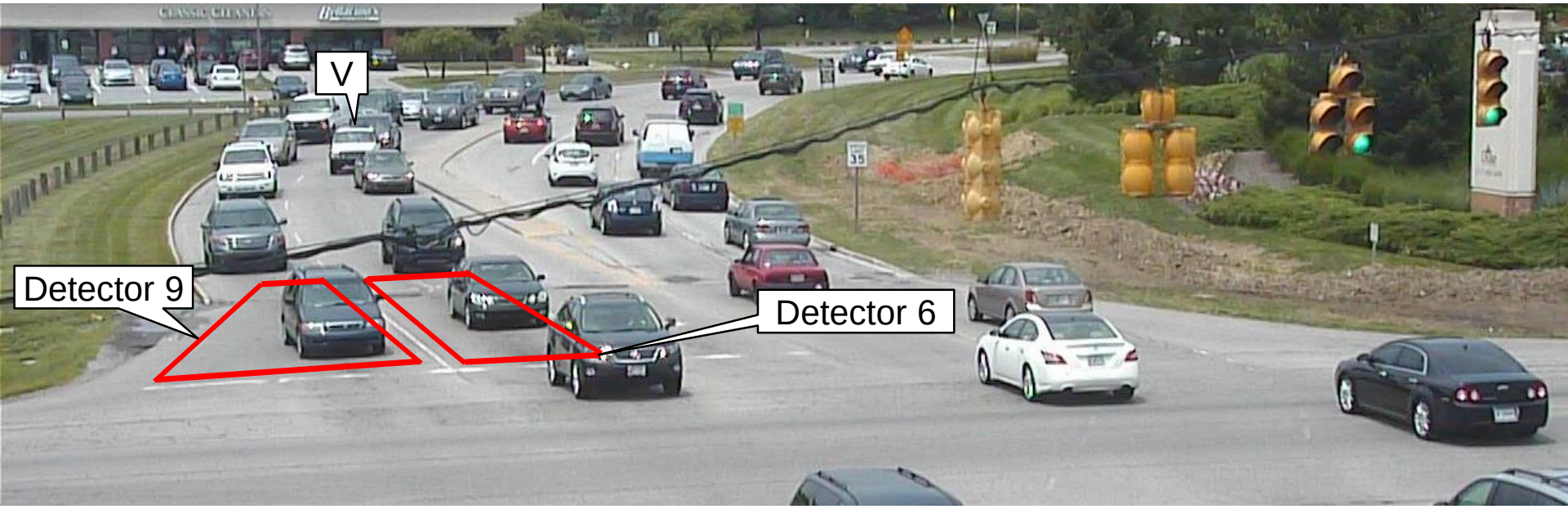
ROR_5 vs. GOR for an Oversaturated Split (Phase 4)

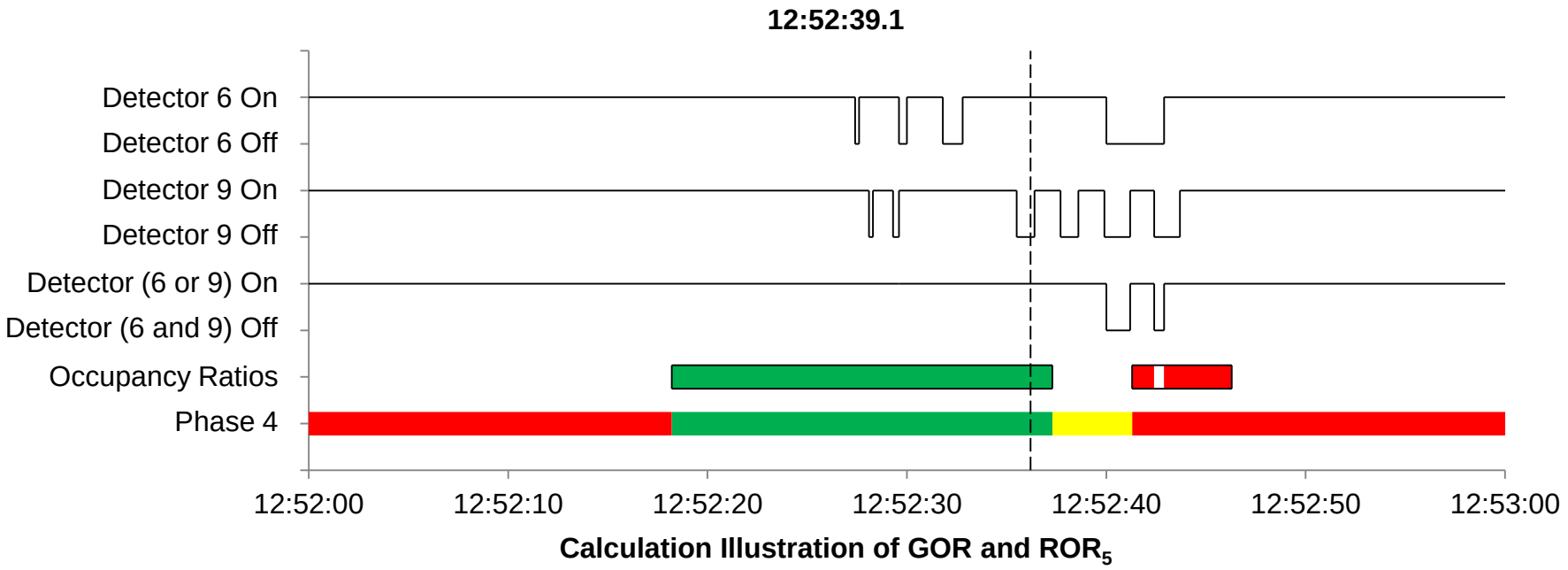




Calculation Illustration of GOR and ROR_5

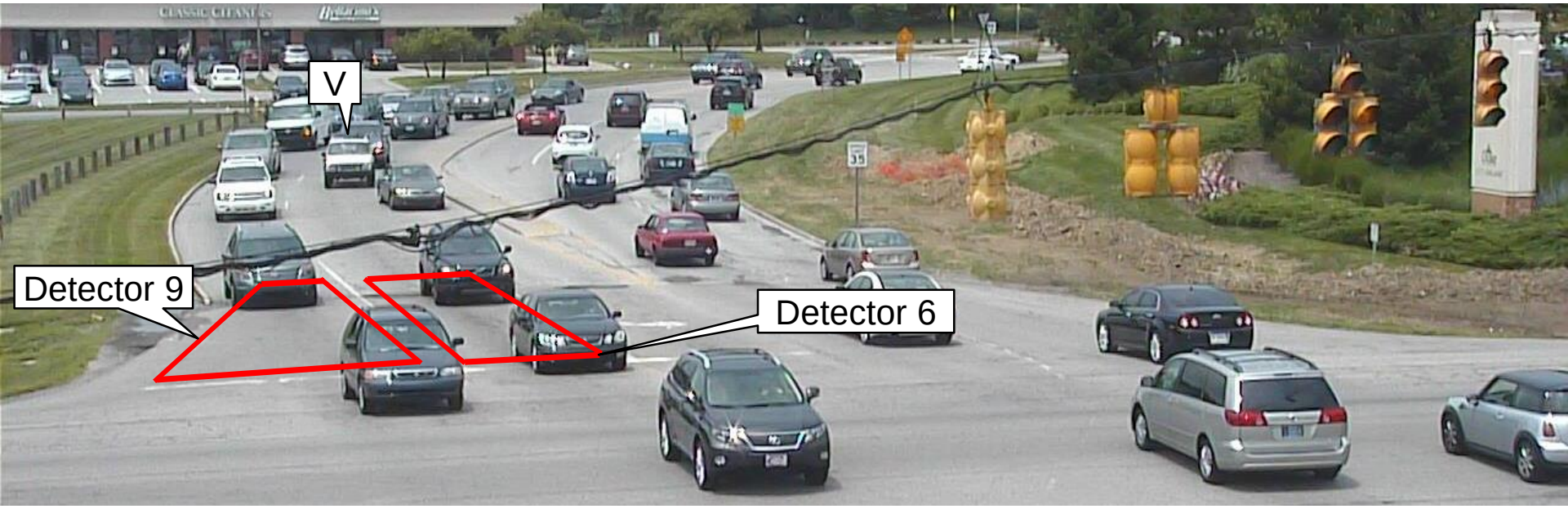
ROR_5 vs. GOR for an Oversaturated Split (Phase 4)

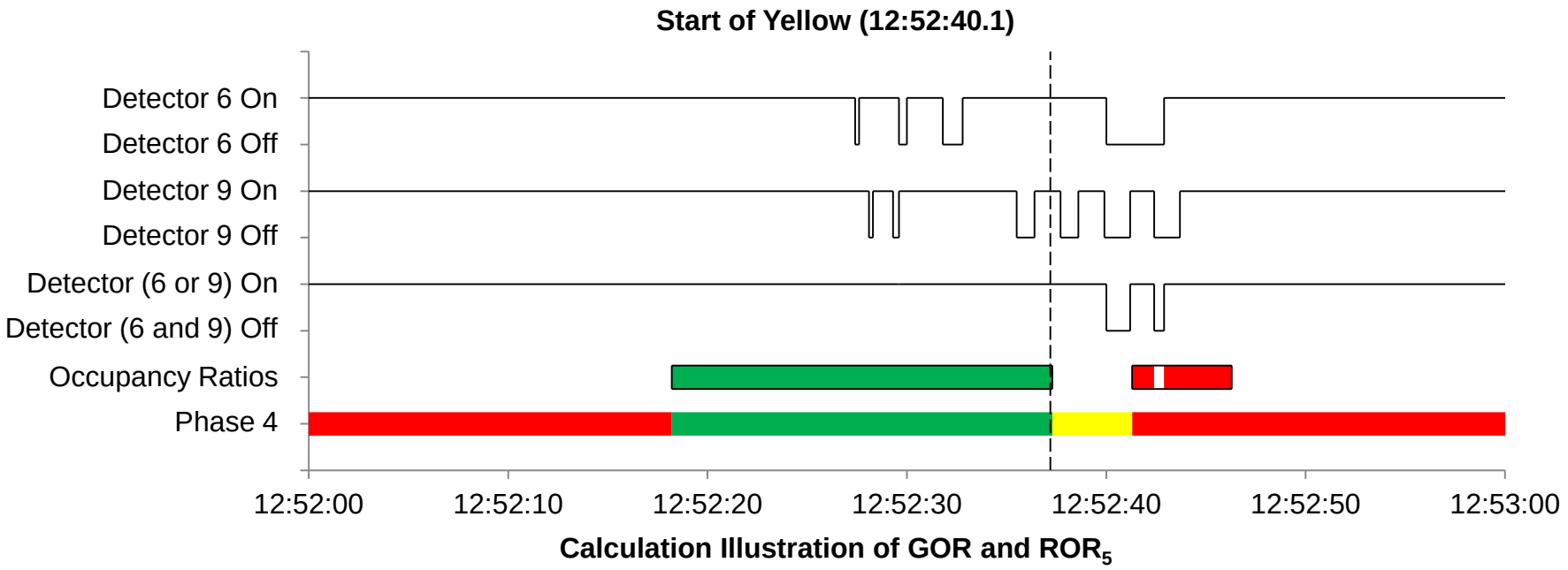




Calculation Illustration of GOR and ROR_5

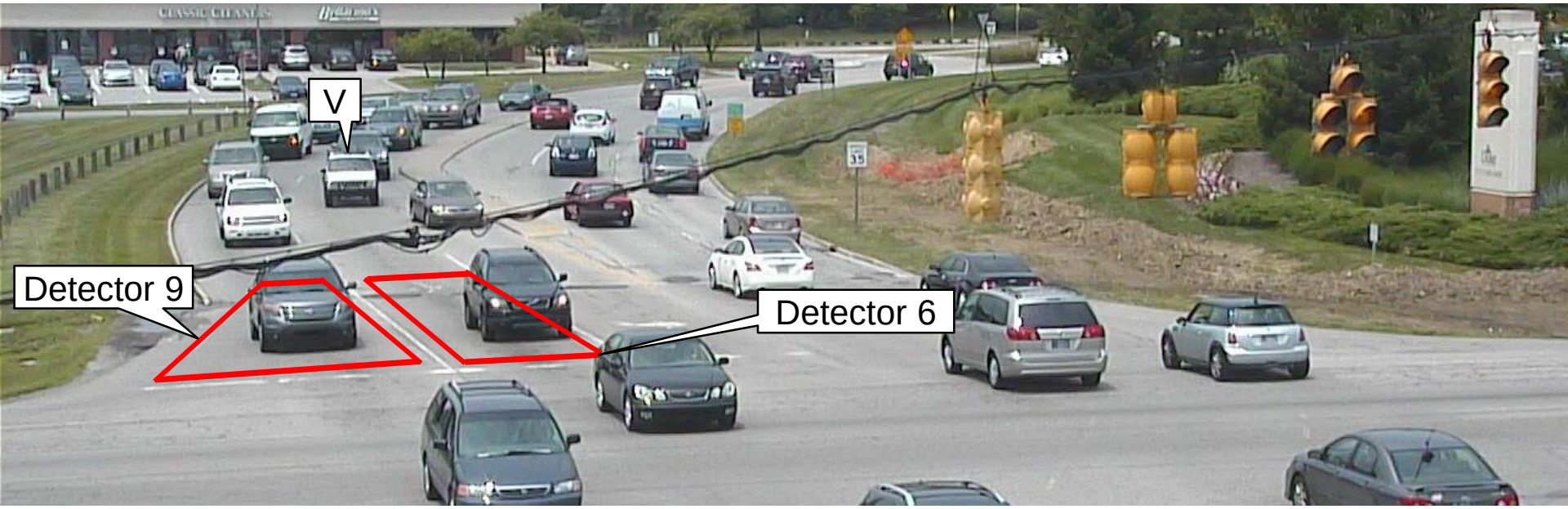
ROR_5 vs. GOR for an Oversaturated Split (Phase 4)

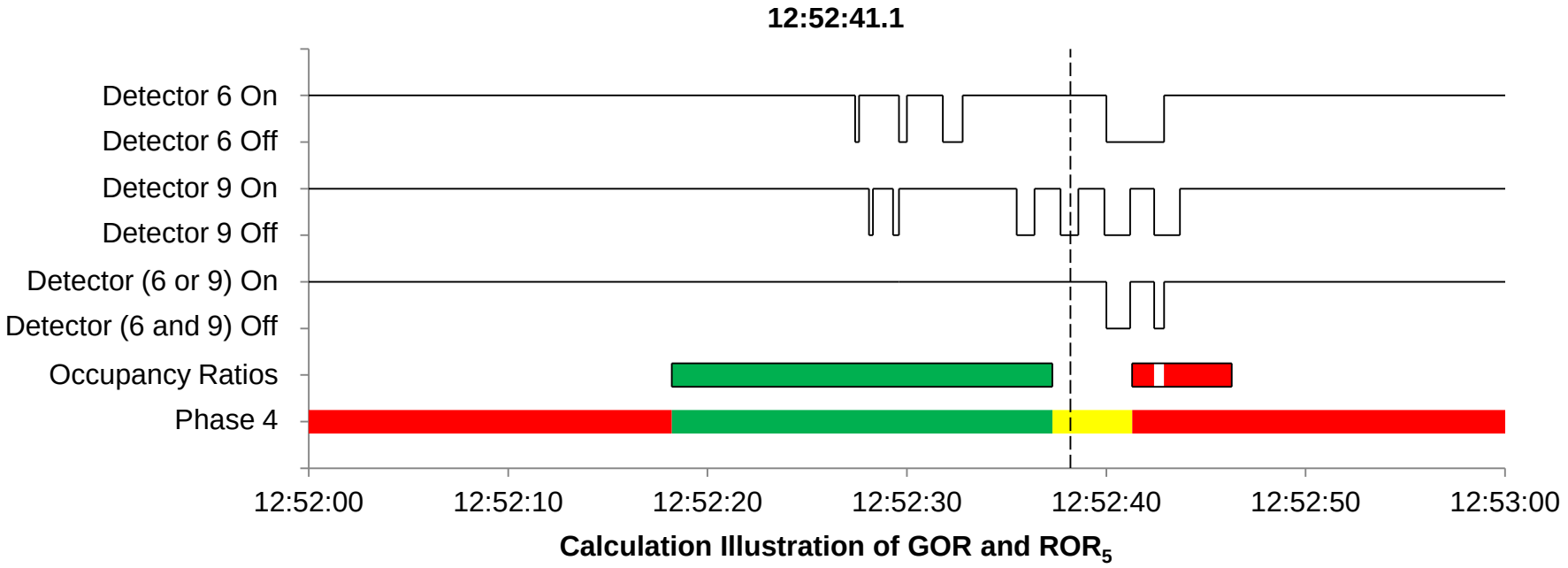




Calculation Illustration of GOR and ROR_5

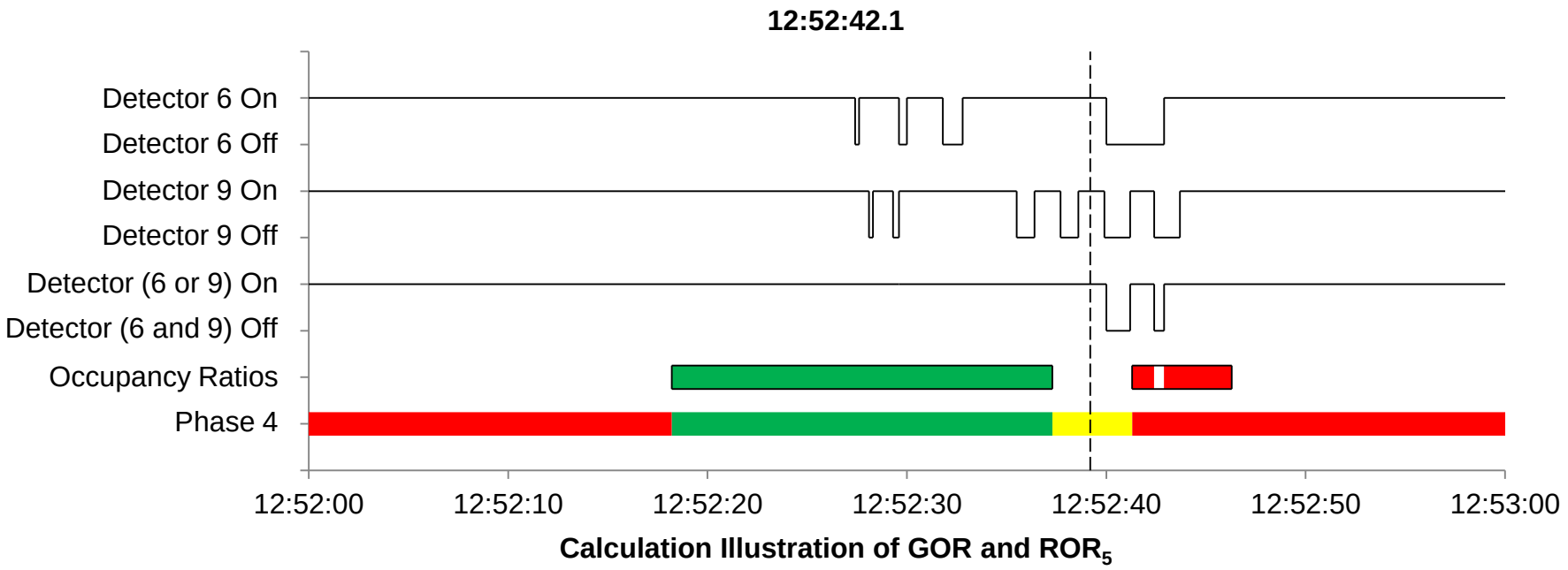
ROR_5 vs. GOR for an Oversaturated Split (Phase 4)





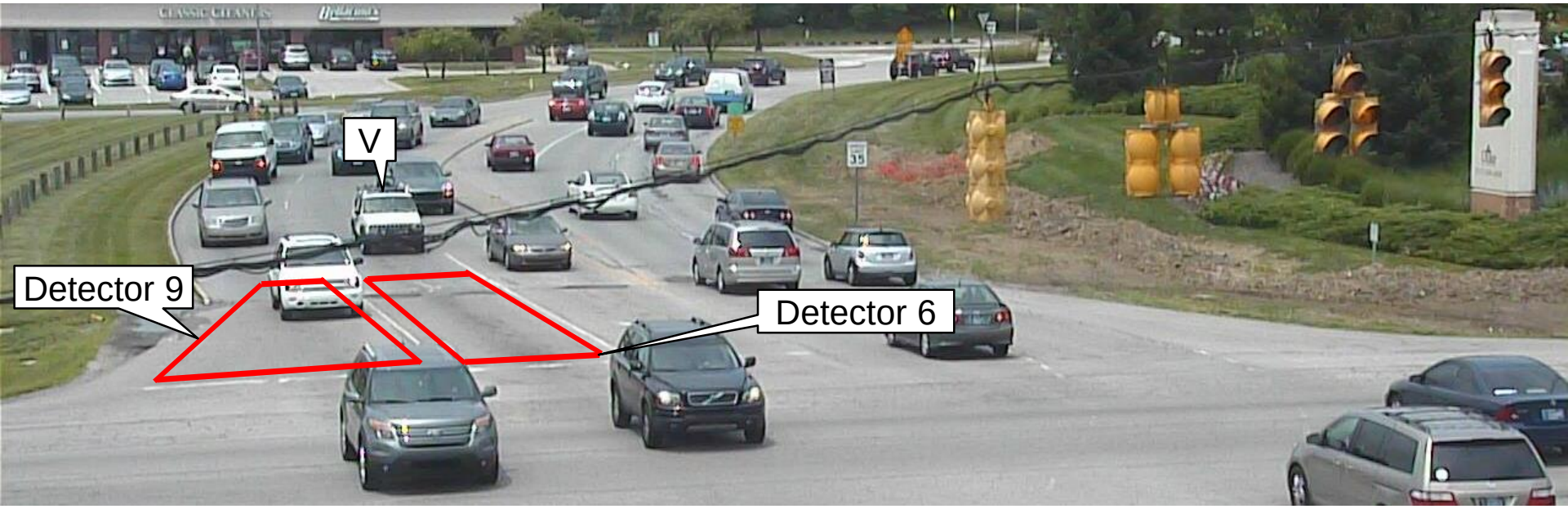
Calculation Illustration of GOR and ROR_5

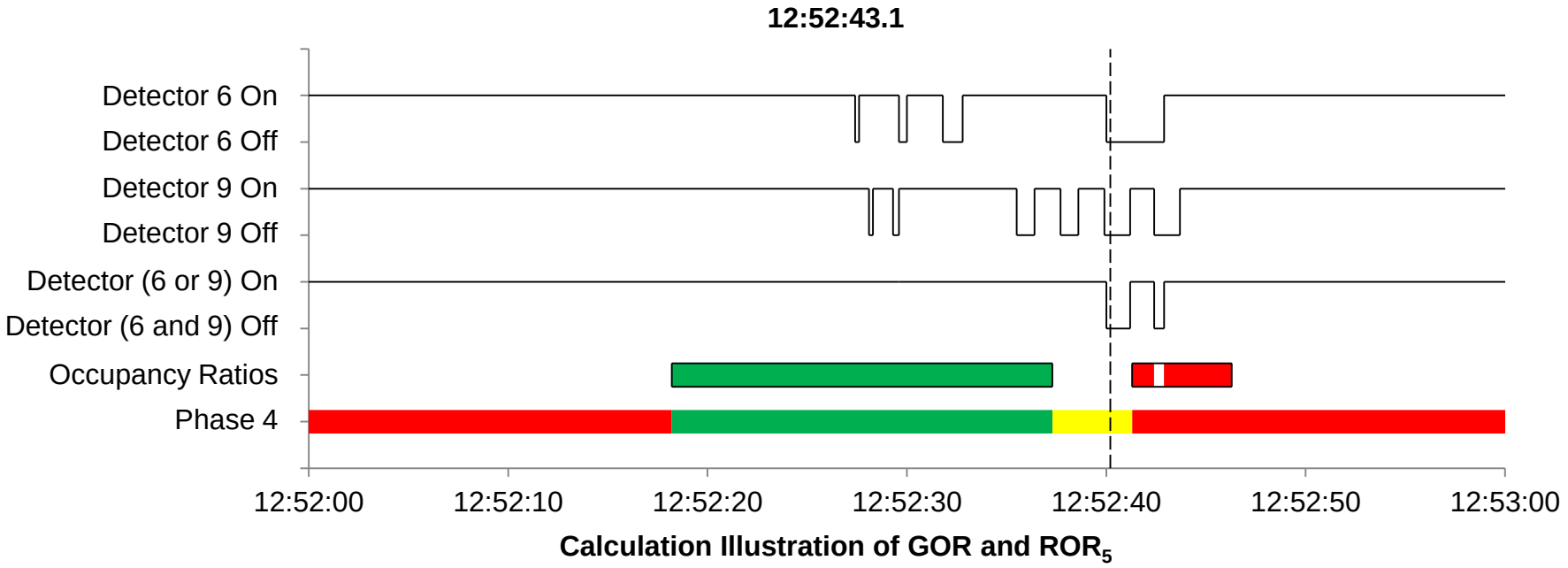
ROR_5 vs. GOR for an Oversaturated Split (Phase 4)



Calculation Illustration of GOR and ROR_5

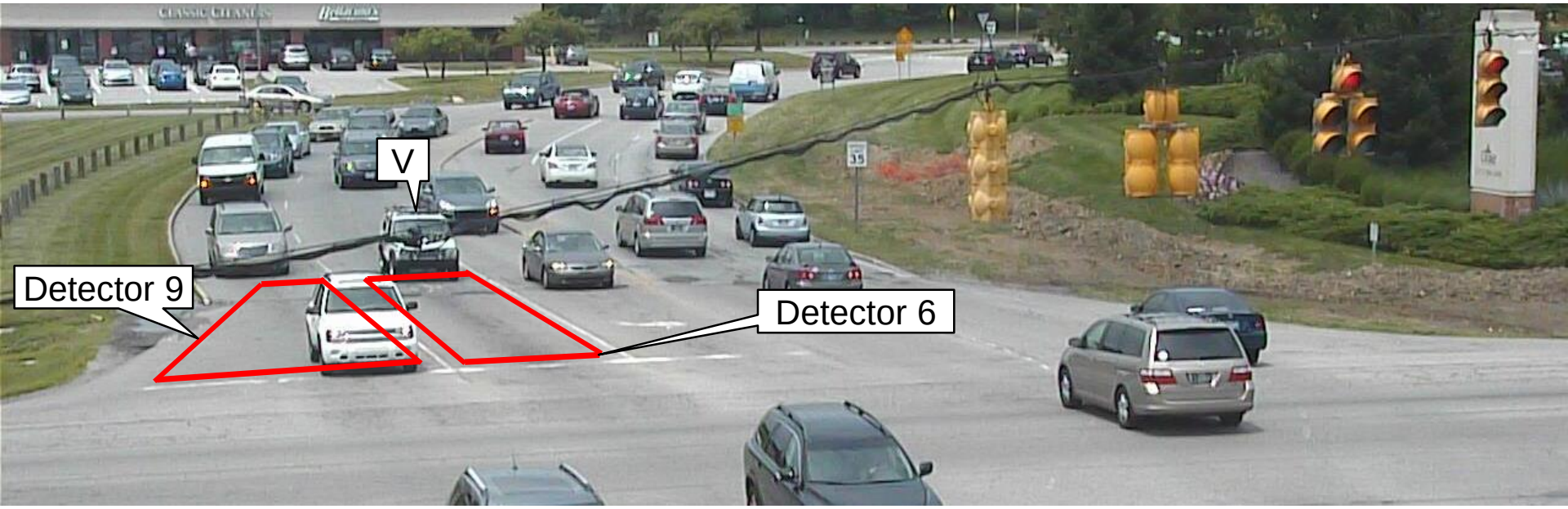
ROR_5 vs. GOR for an Oversaturated Split (Phase 4)

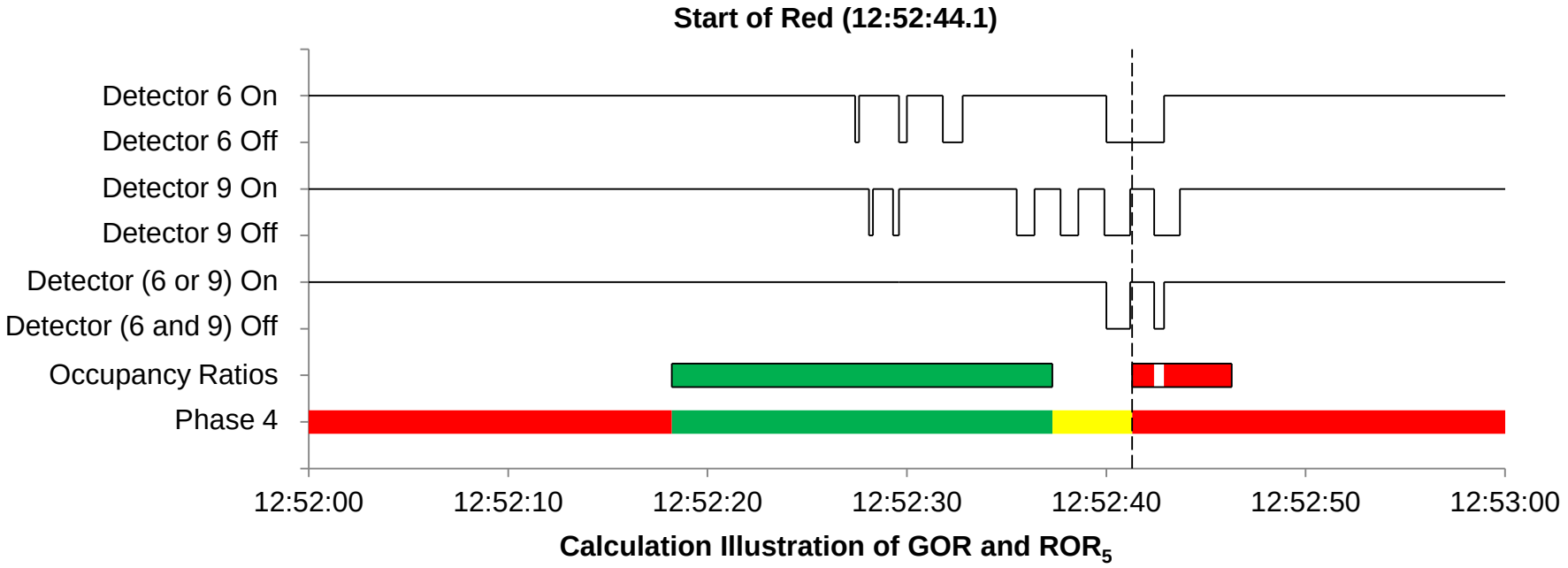




Calculation Illustration of GOR and ROR_5

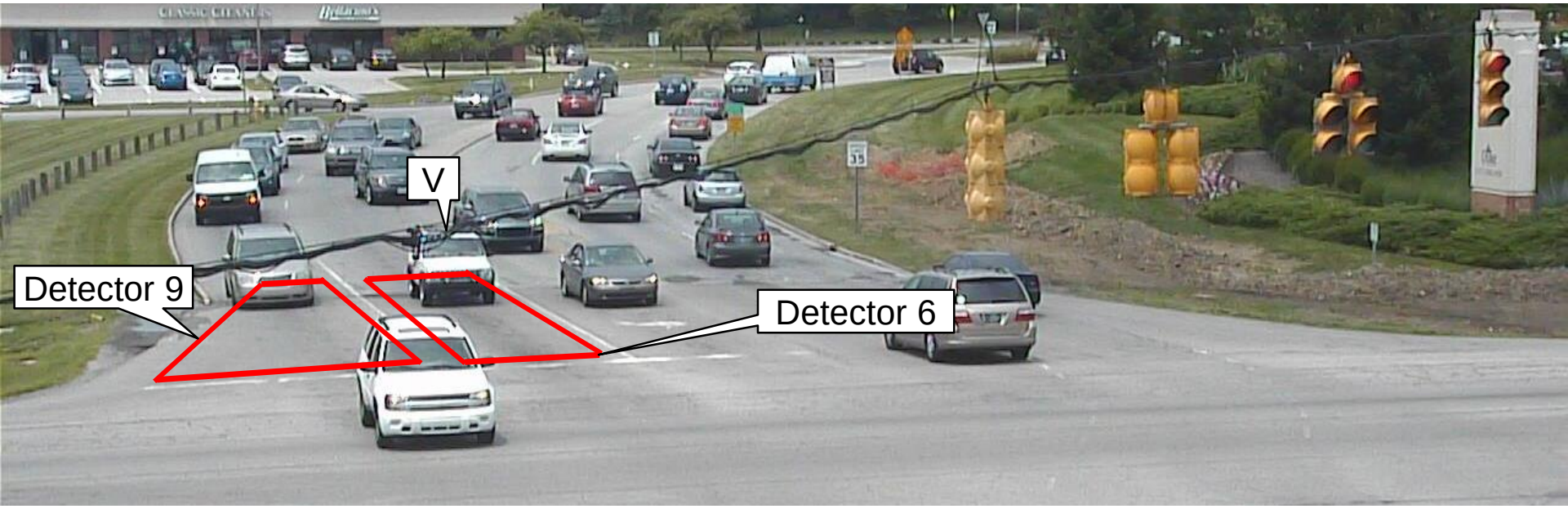
ROR_5 vs. GOR for an Oversaturated Split (Phase 4)

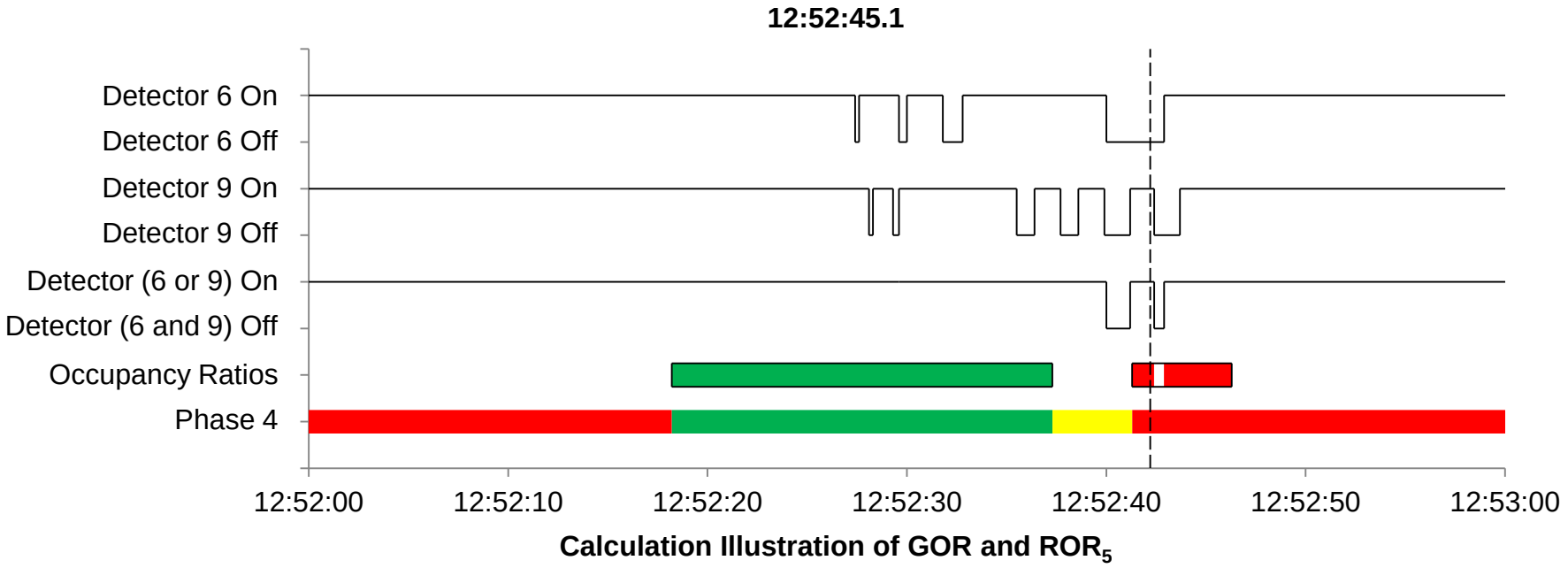




Calculation Illustration of GOR and ROR_5

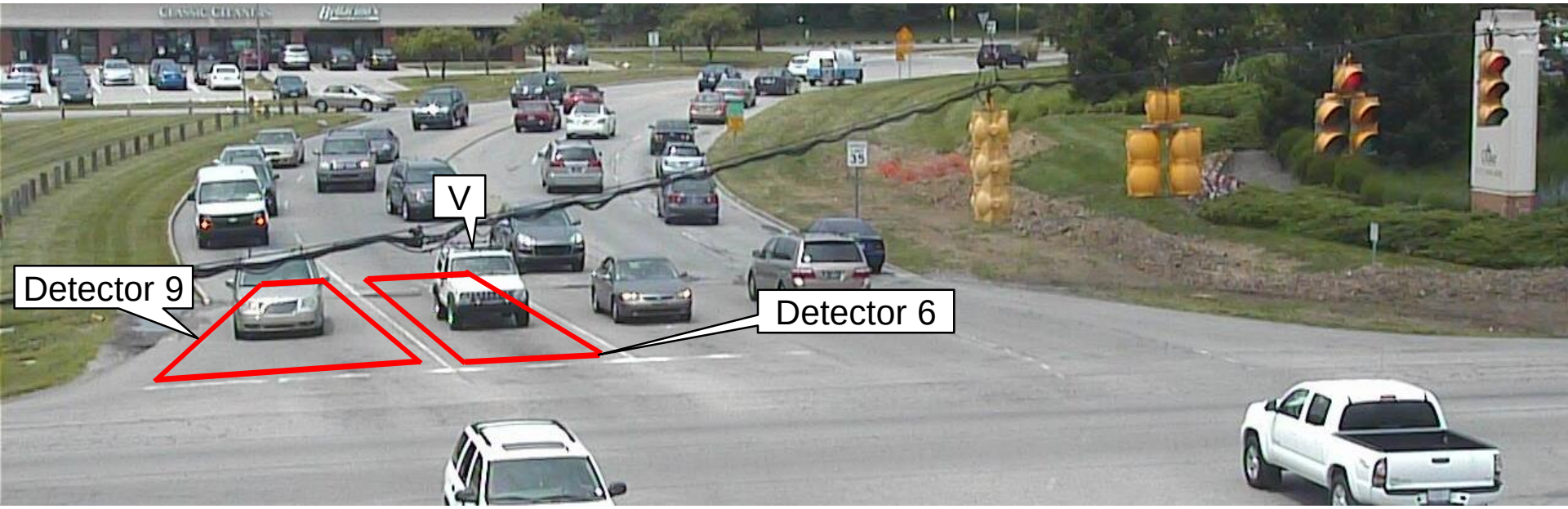
ROR_5 vs. GOR for an Oversaturated Split (Phase 4)

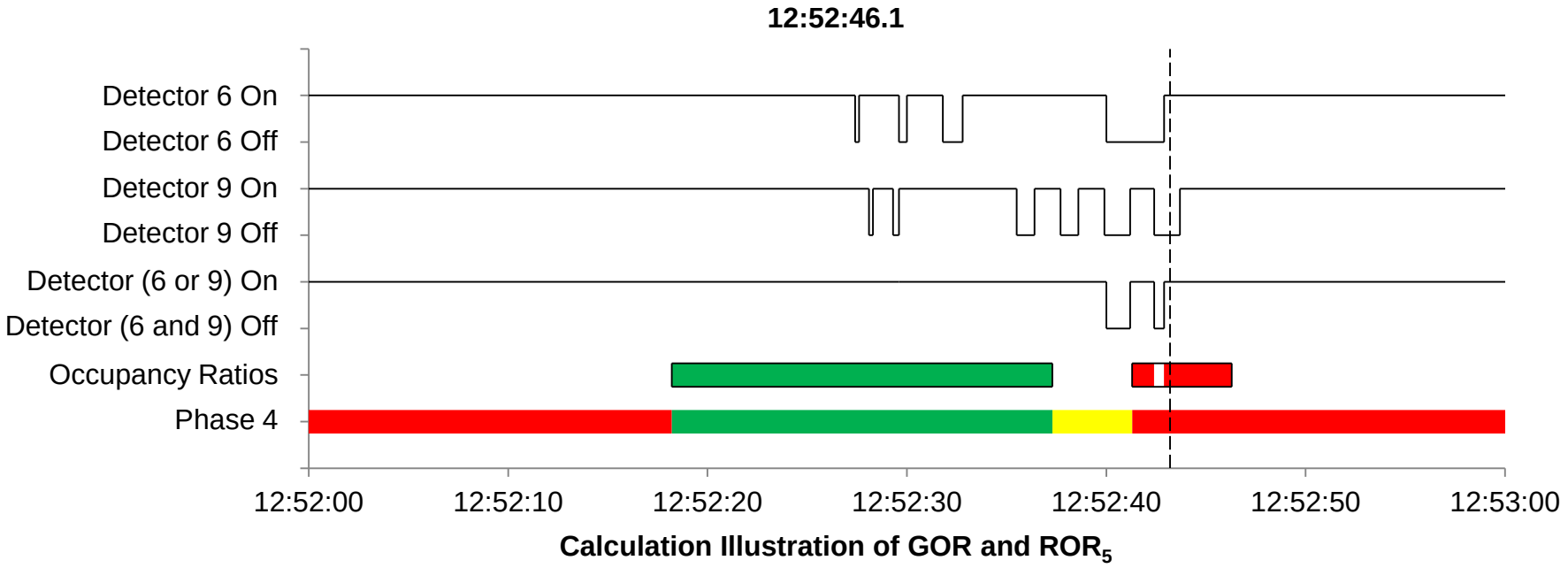




Calculation Illustration of GOR and ROR_5

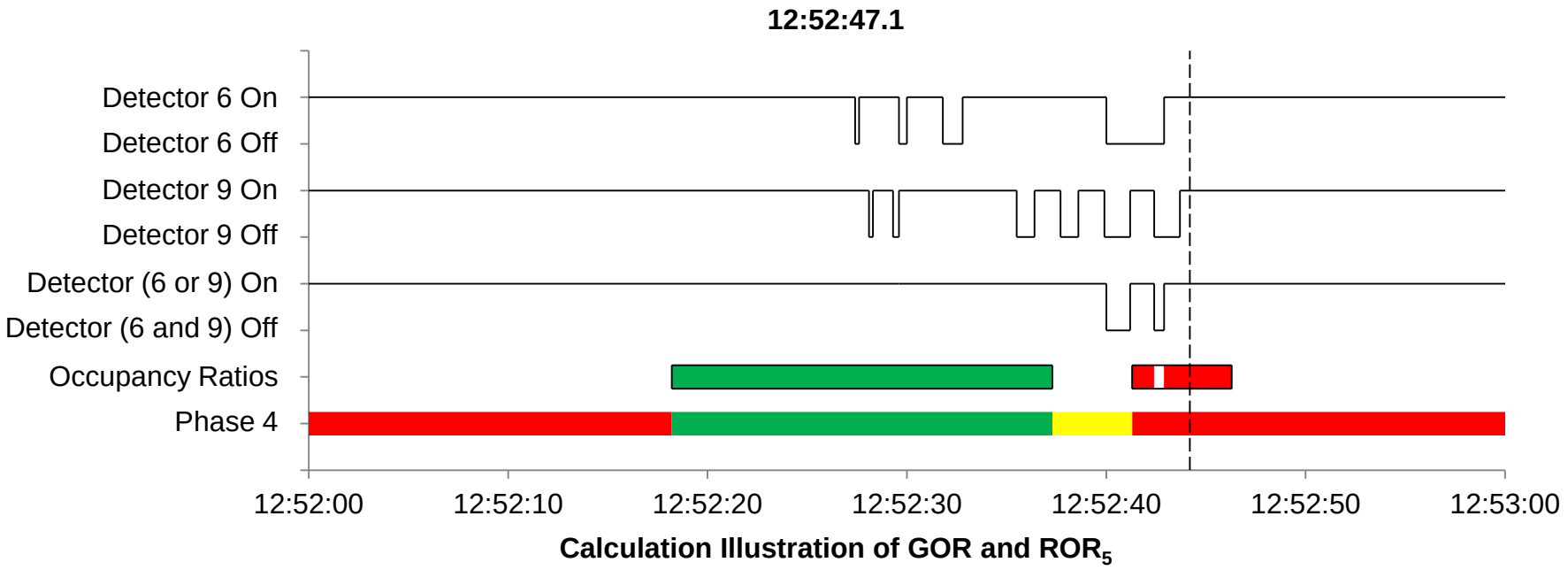
ROR_5 vs. GOR for an Oversaturated Split (Phase 4)





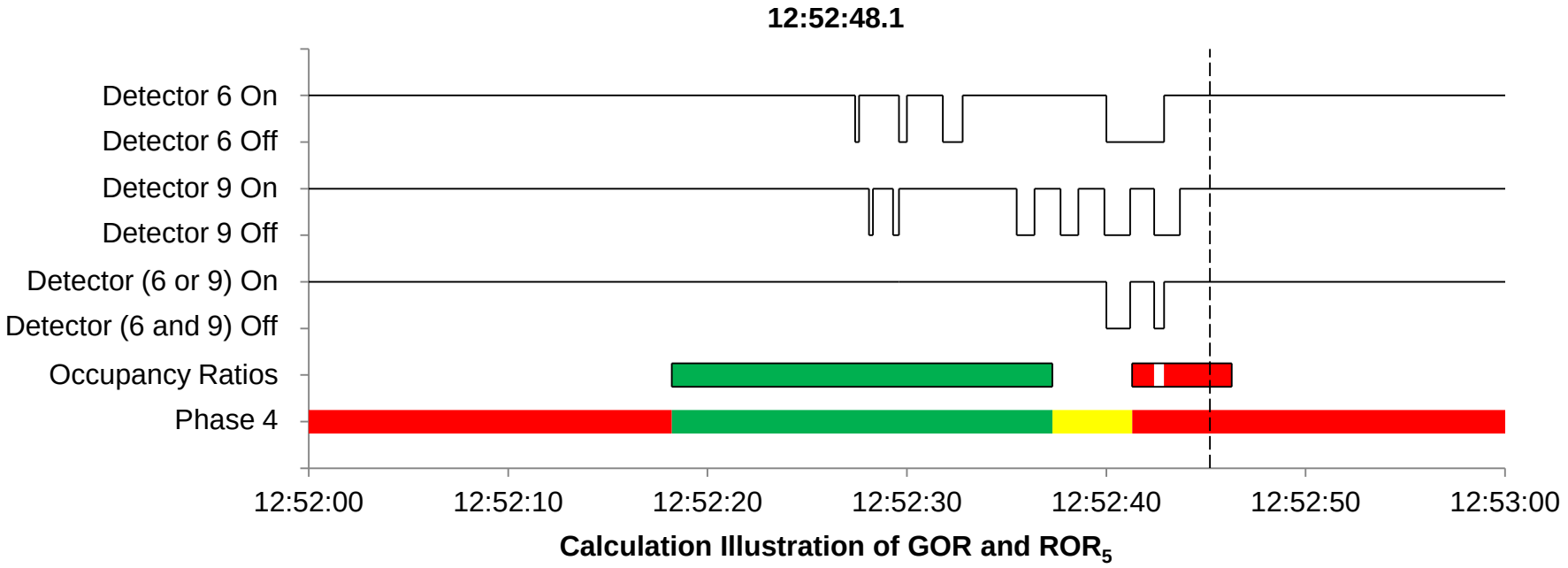
Calculation Illustration of GOR and ROR_5

ROR_5 vs. GOR for an Oversaturated Split (Phase 4)



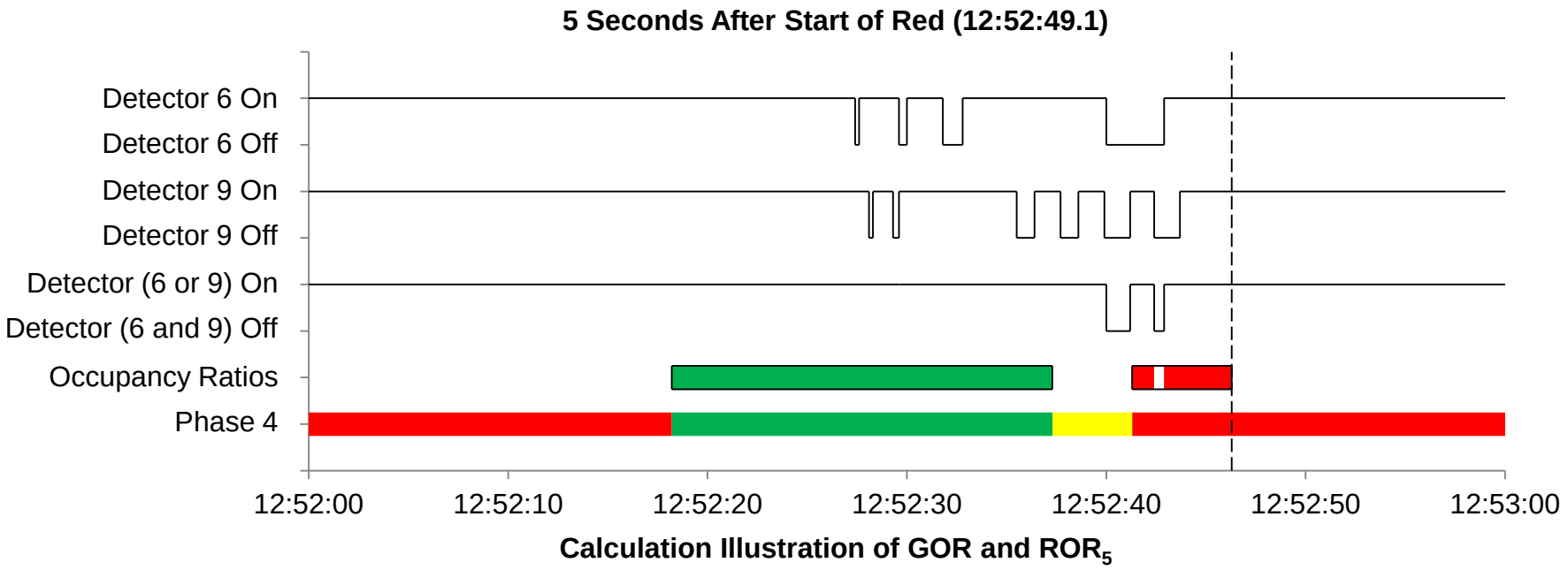
Calculation Illustration of GOR and ROR_5

ROR_5 vs. GOR for an Oversaturated Split (Phase 4)

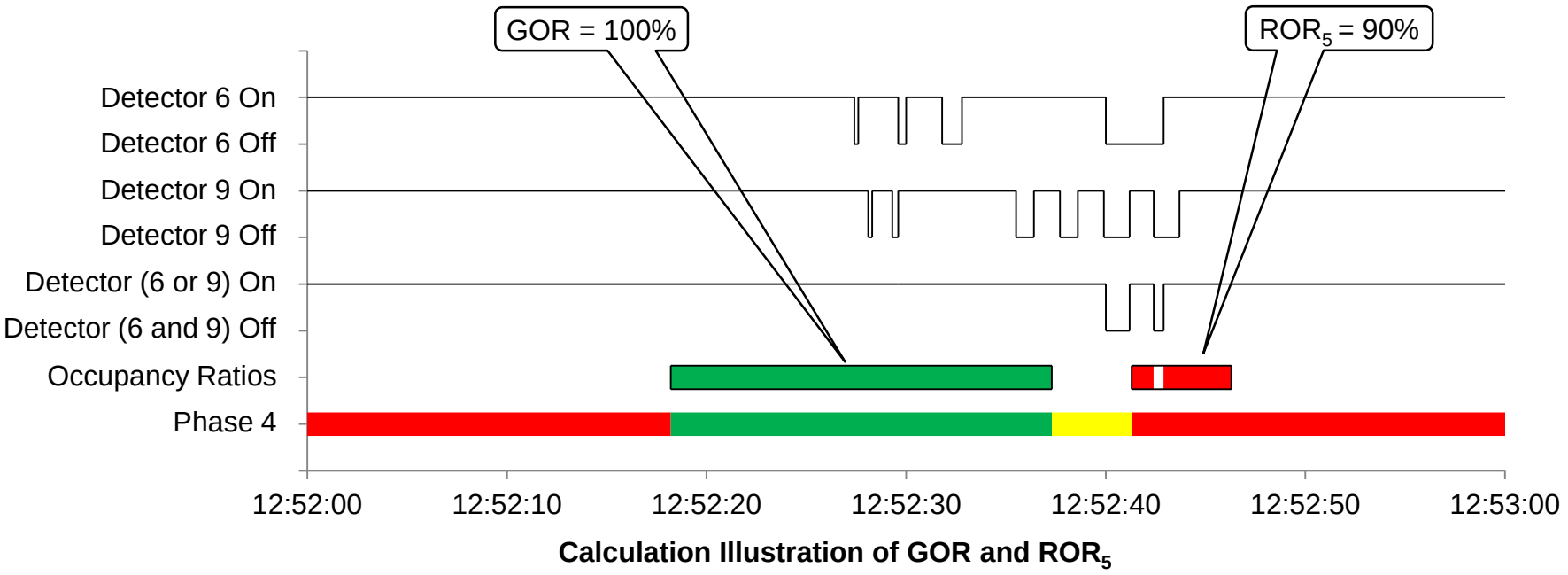


Calculation Illustration of GOR and ROR_5

ROR_5 vs. GOR for an Oversaturated Split (Phase 4)

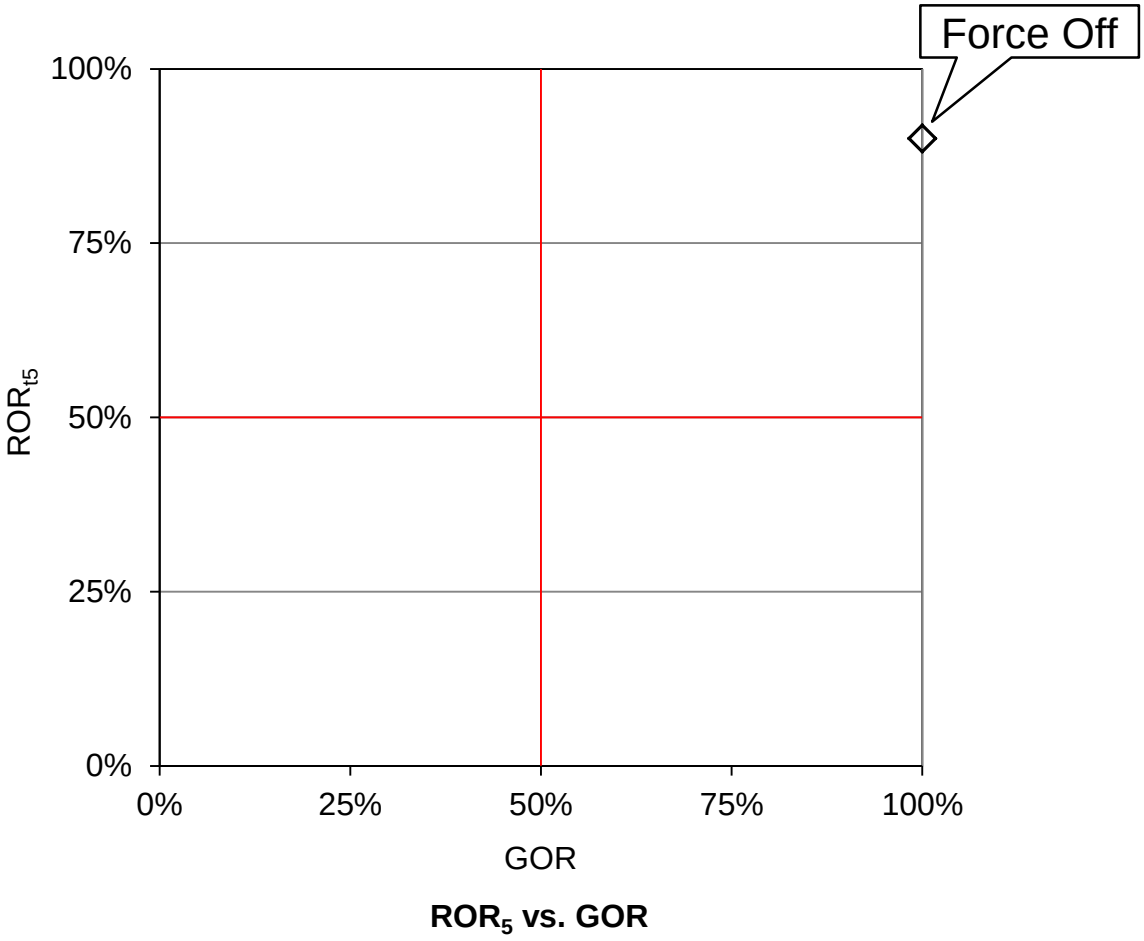


ROR_5 vs. GOR for an Oversaturated Split (Phase 4)

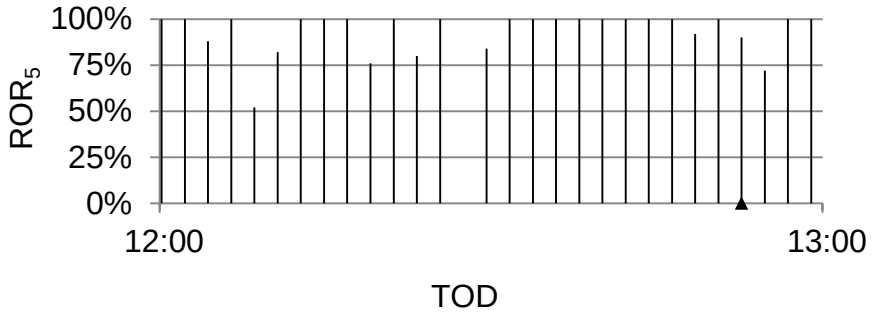


Calculation Illustration of GOR and ROR_5

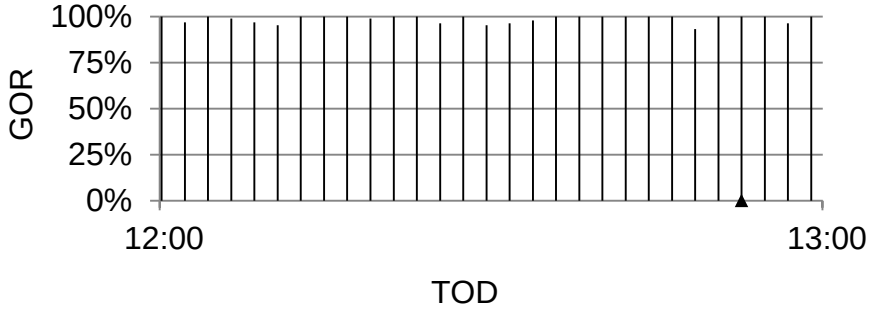
ROR_5 vs. GOR for an Oversaturated Split (Phase 4)



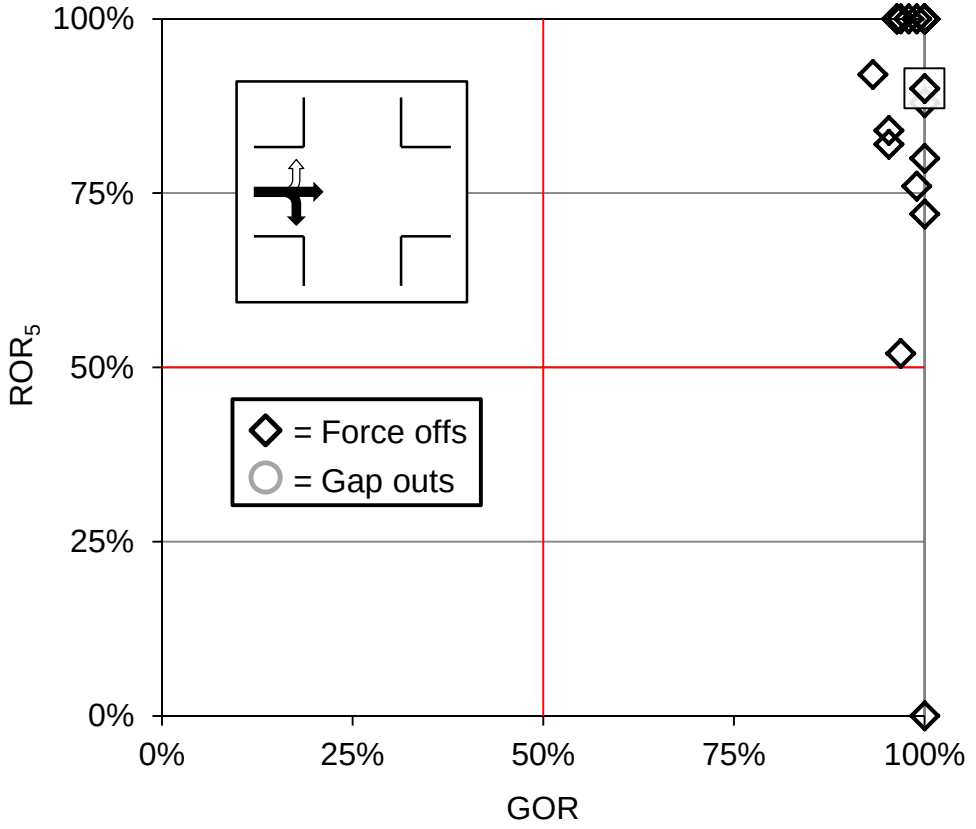
ROR_5 vs. GOR Plot for an Oversaturated Thru Movement



ROR_5 vs. TOD (1200-1300)

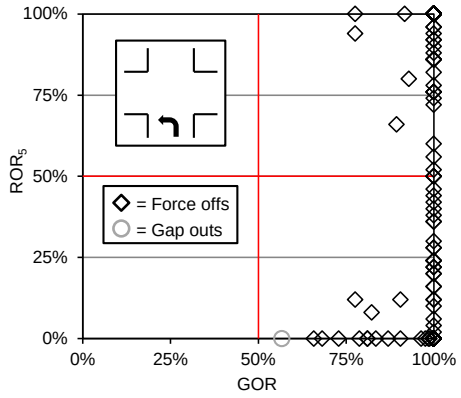


GOR vs. TOD (1200-1300)

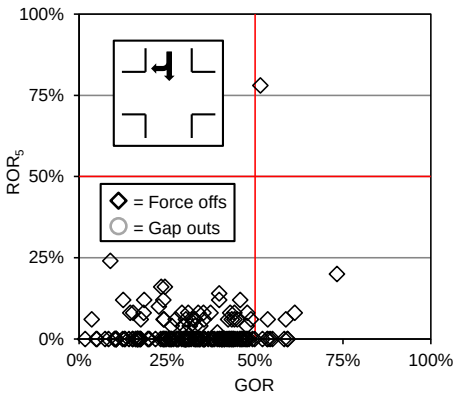


ROR_5 vs. GOR (1200-1300)

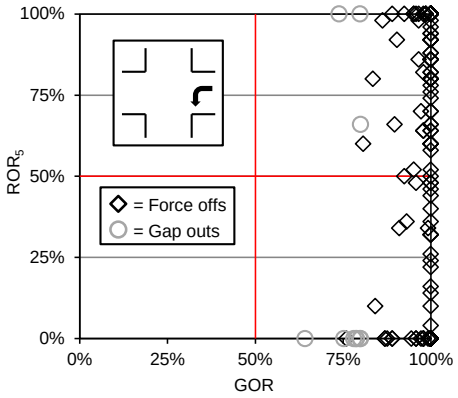
ROR_5 vs. GOR and/or V/C Ratio Summary (0900-1500)



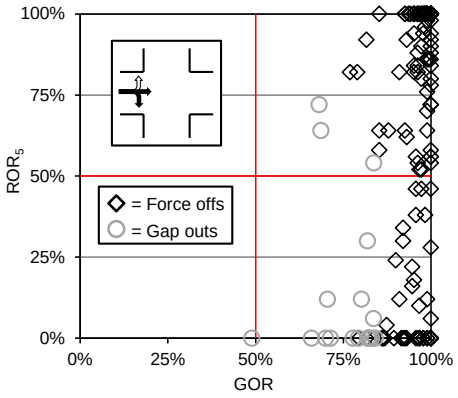
Phase 1 ROR_5 vs. GOR



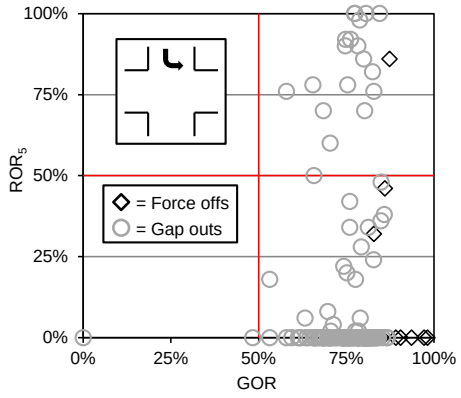
Phase 2 ROR_5 vs. GOR



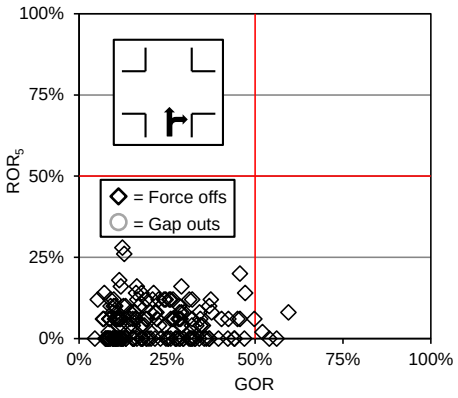
Phase 3 ROR_5 vs. GOR



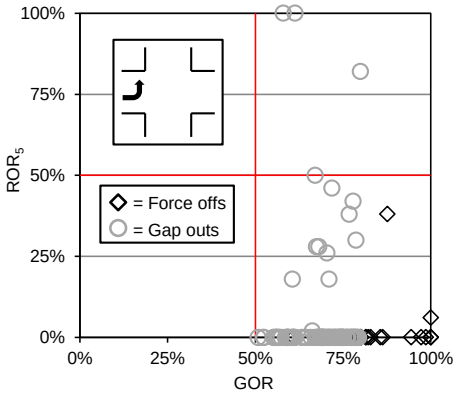
Phase 4 ROR_5 vs. GOR



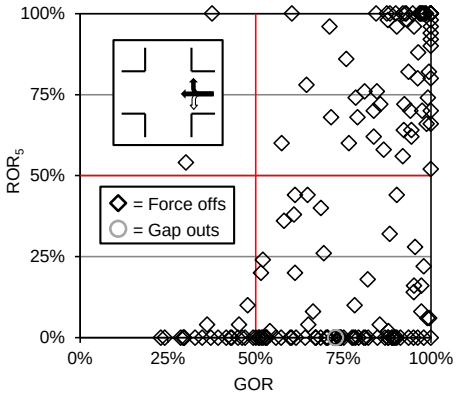
Phase 5 ROR_5 vs. GOR



Phase 6 ROR_5 vs. GOR

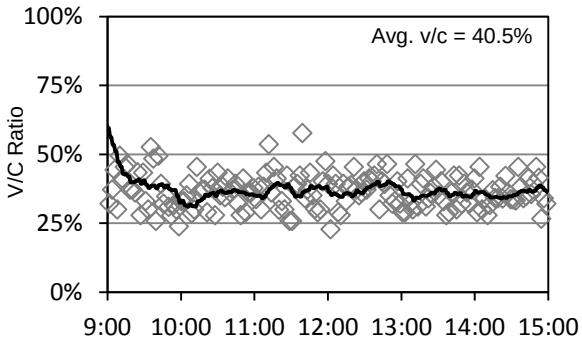


Phase 7 ROR_5 vs. GOR

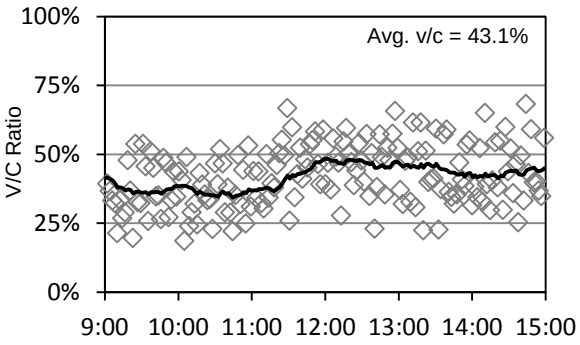


Phase 8 ROR_5 vs. GOR

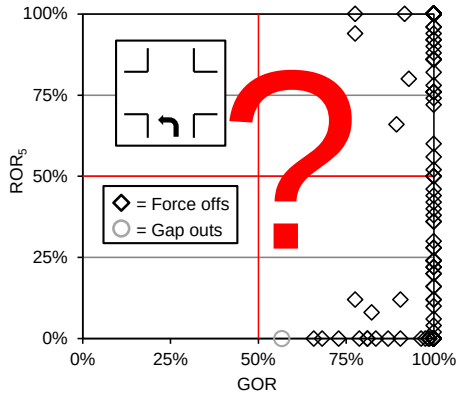
Phase 2 V/C Ratio



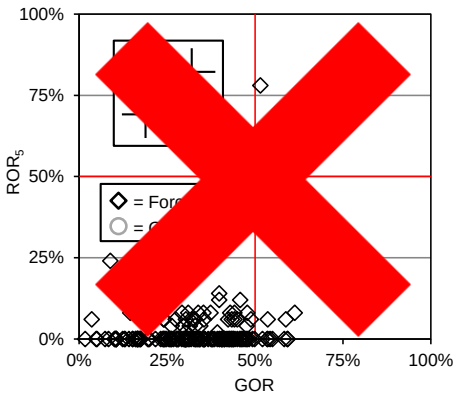
Phase 6 V/C Ratio



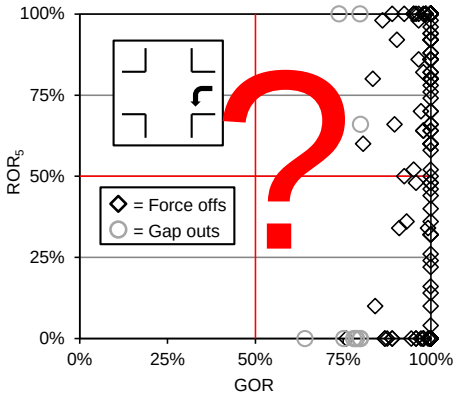
ROR_5 vs. GOR and/or V/C Ratio Summary (0900-1500)



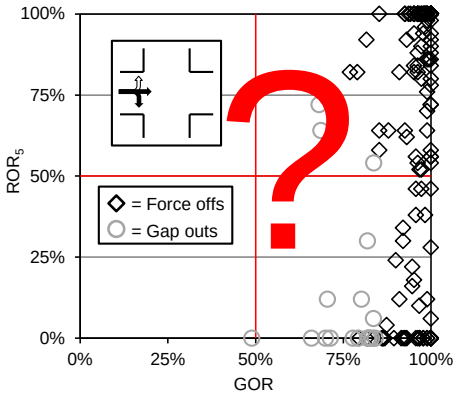
Phase 1 ROR_5 vs. GOR



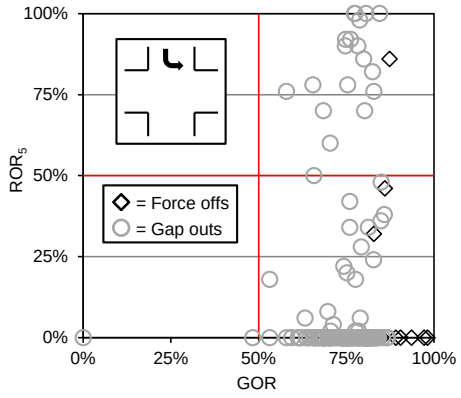
Phase 2 ROR_5 vs. GOR



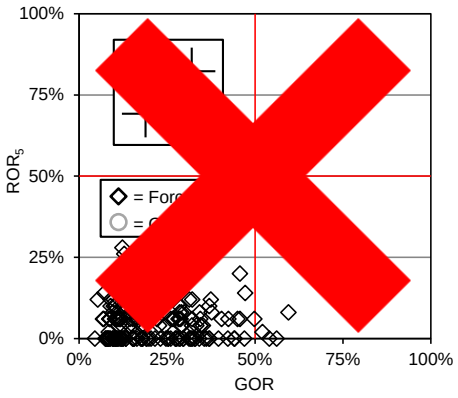
Phase 3 ROR_5 vs. GOR



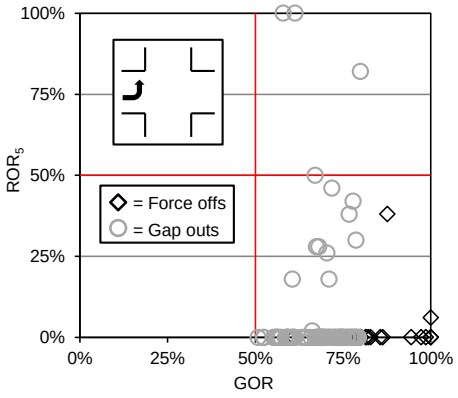
Phase 4 ROR_5 vs. GOR



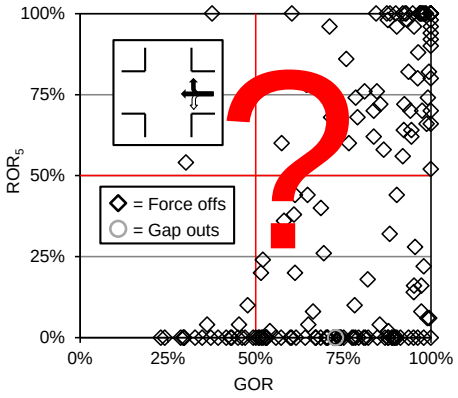
Phase 5 ROR_5 vs. GOR



Phase 6 ROR_5 vs. GOR

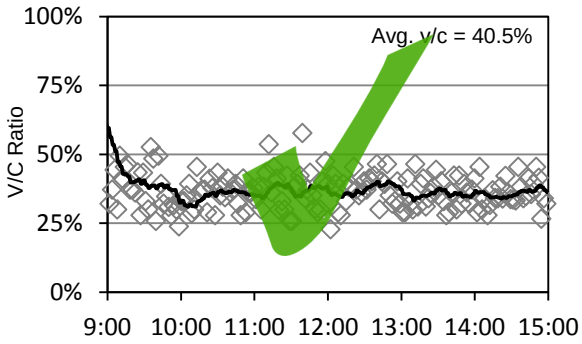


Phase 7 ROR_5 vs. GOR

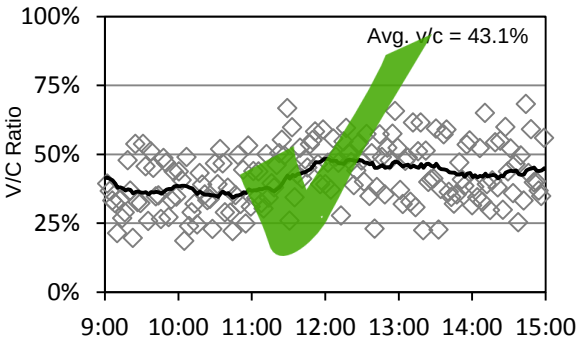


Phase 8 ROR_5 vs. GOR

Phase 2 V/C Ratio

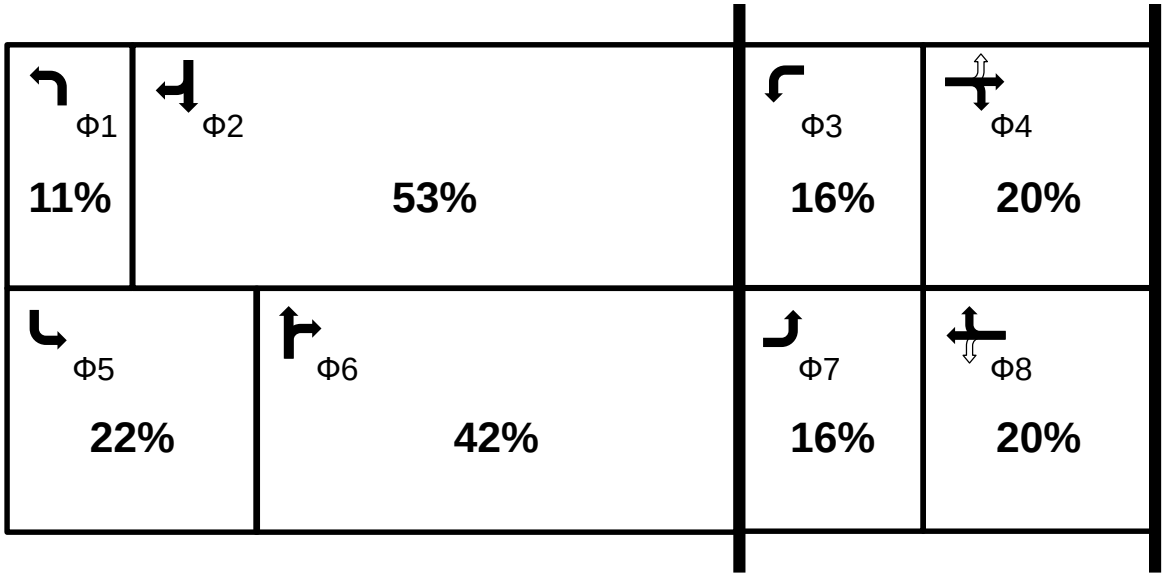


Phase 6 V/C Ratio

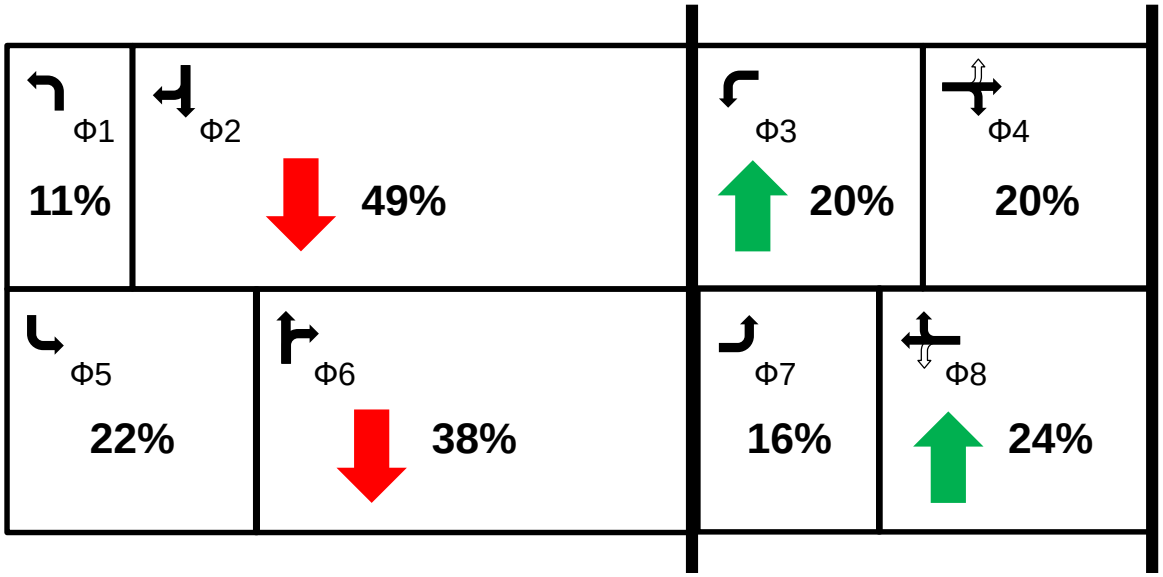


Split Time Adjustment (0900-1500)

Before

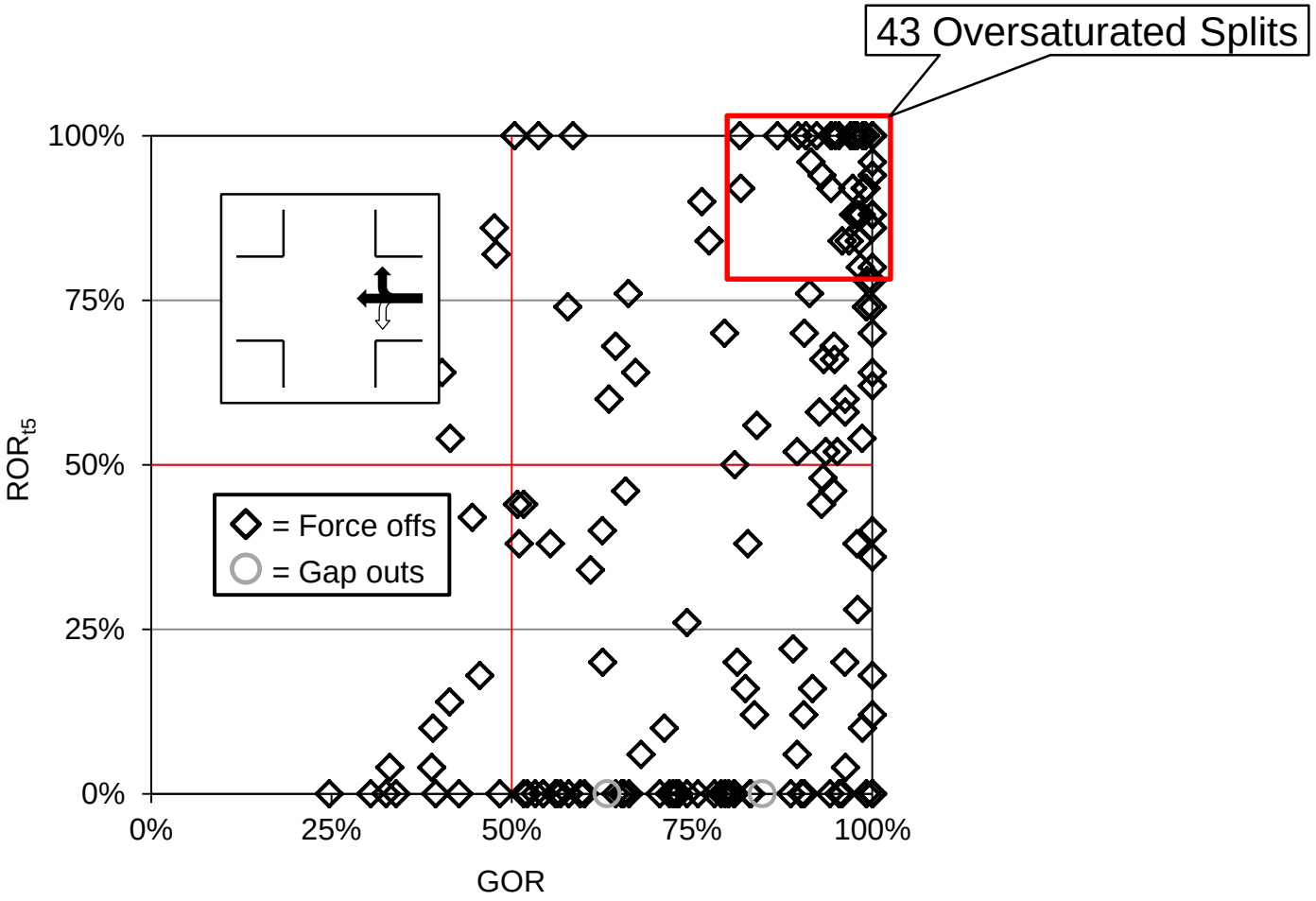


After



Phase 8 Before and After Comparison (0900-1500)

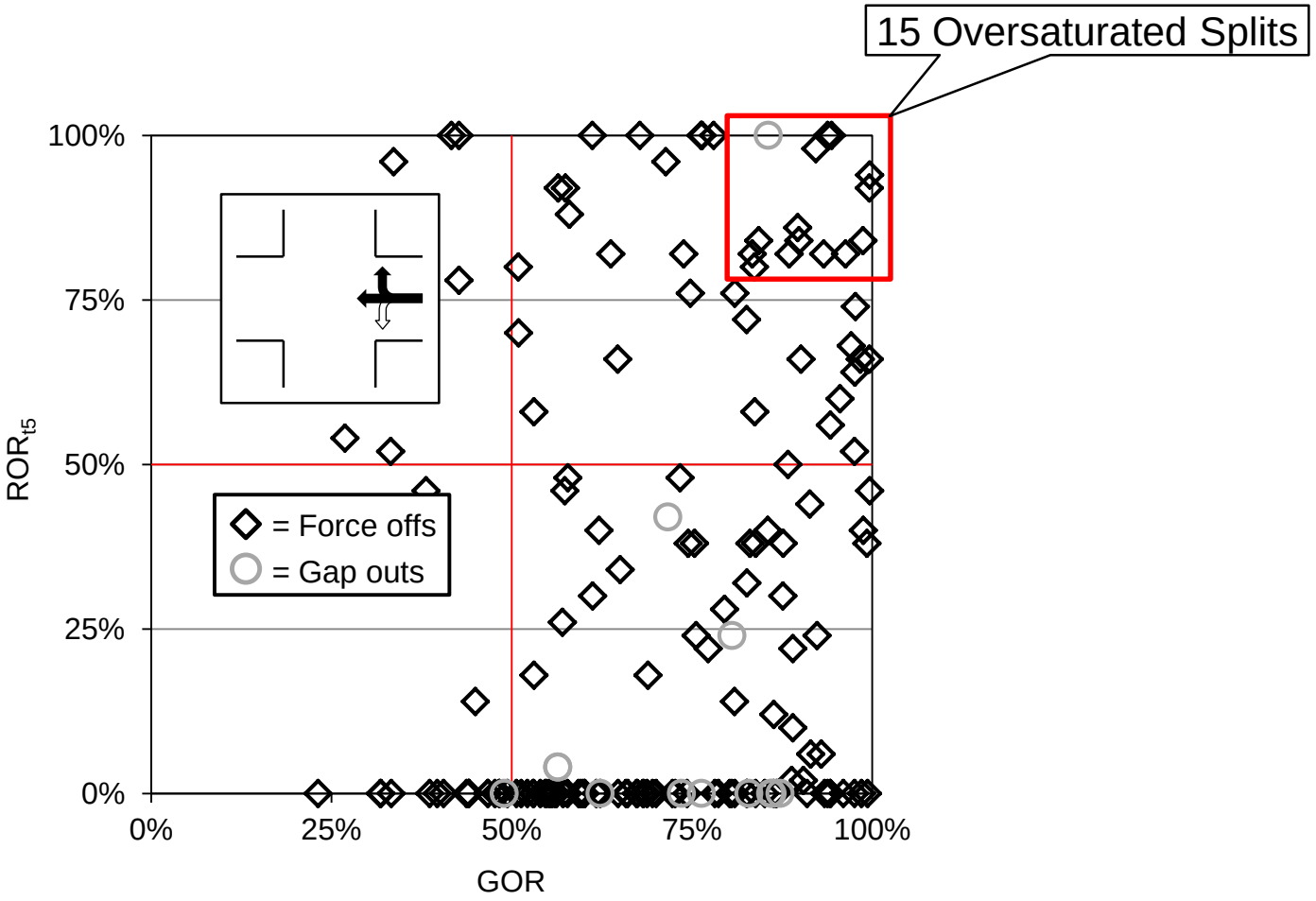
Before



ROR_5 vs. GOR (Thurs. 7/18)

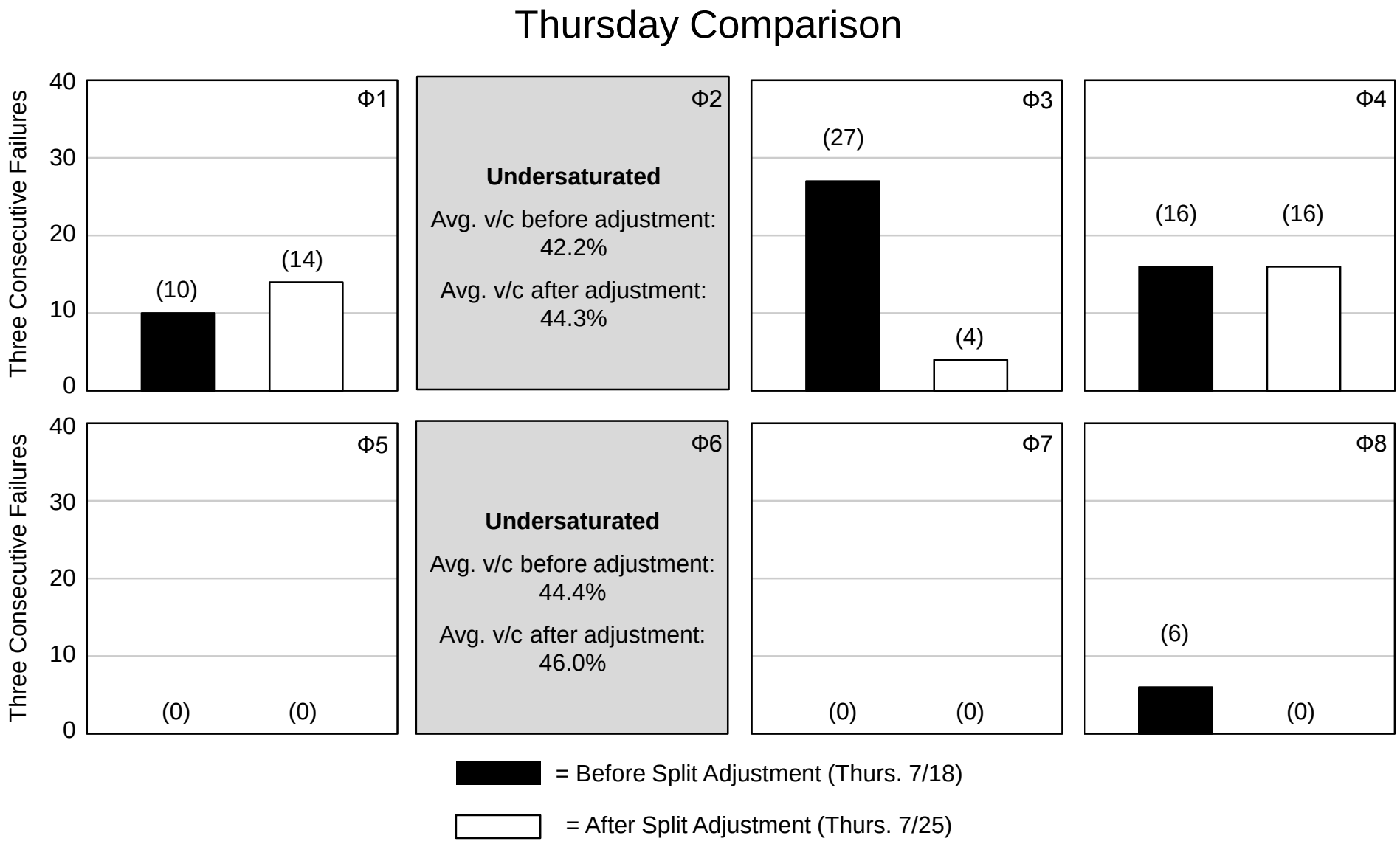
Phase 8 Before and After Comparison (0900-1500)

After

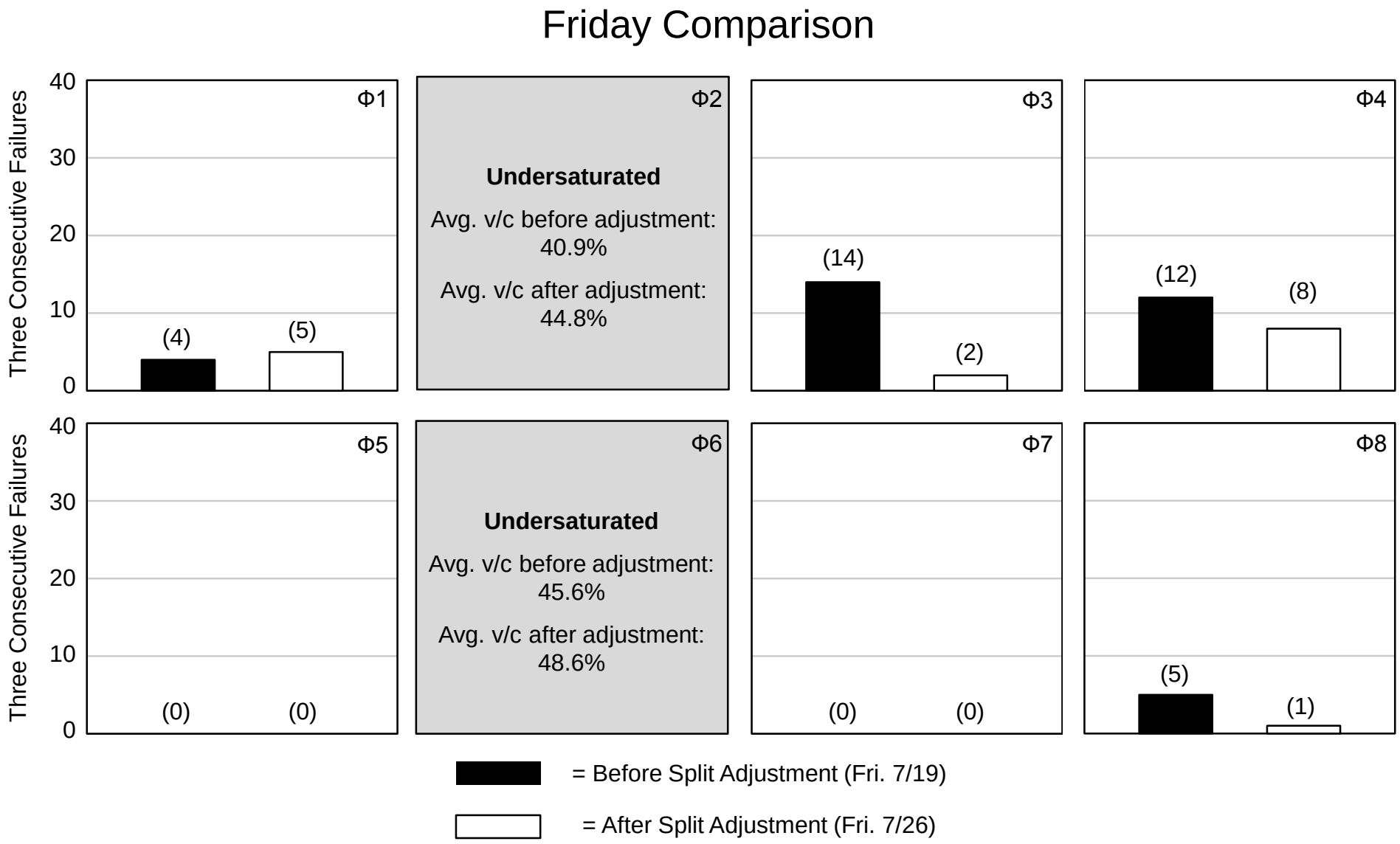


ROR_5 vs. GOR (Thurs. 7/25)

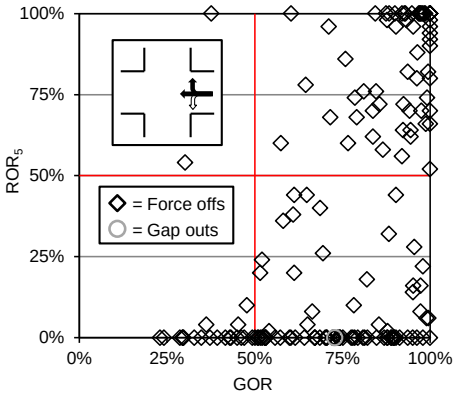
Bar Charts of Three Consecutive Split Failures (0900-1500)

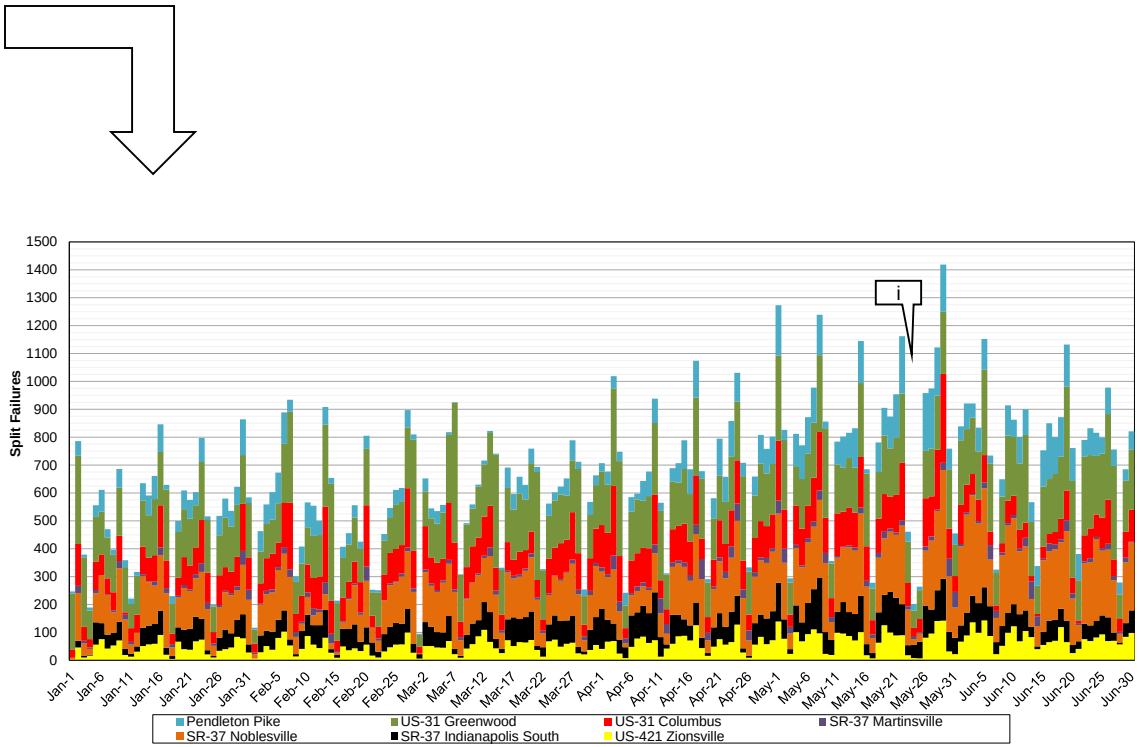


Bar Charts of Three Consecutive Split Failures (0900-1500)

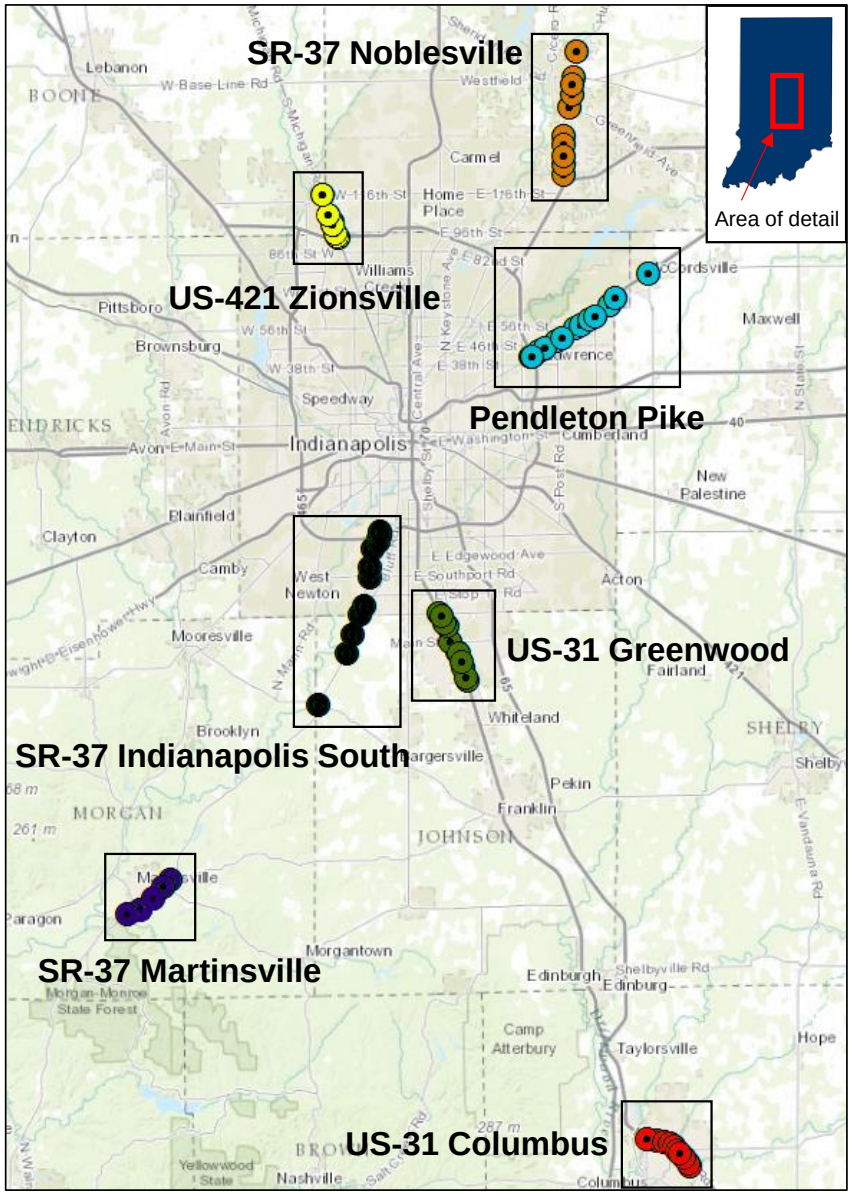


Application of the Concept to Signal Performance Measures Data



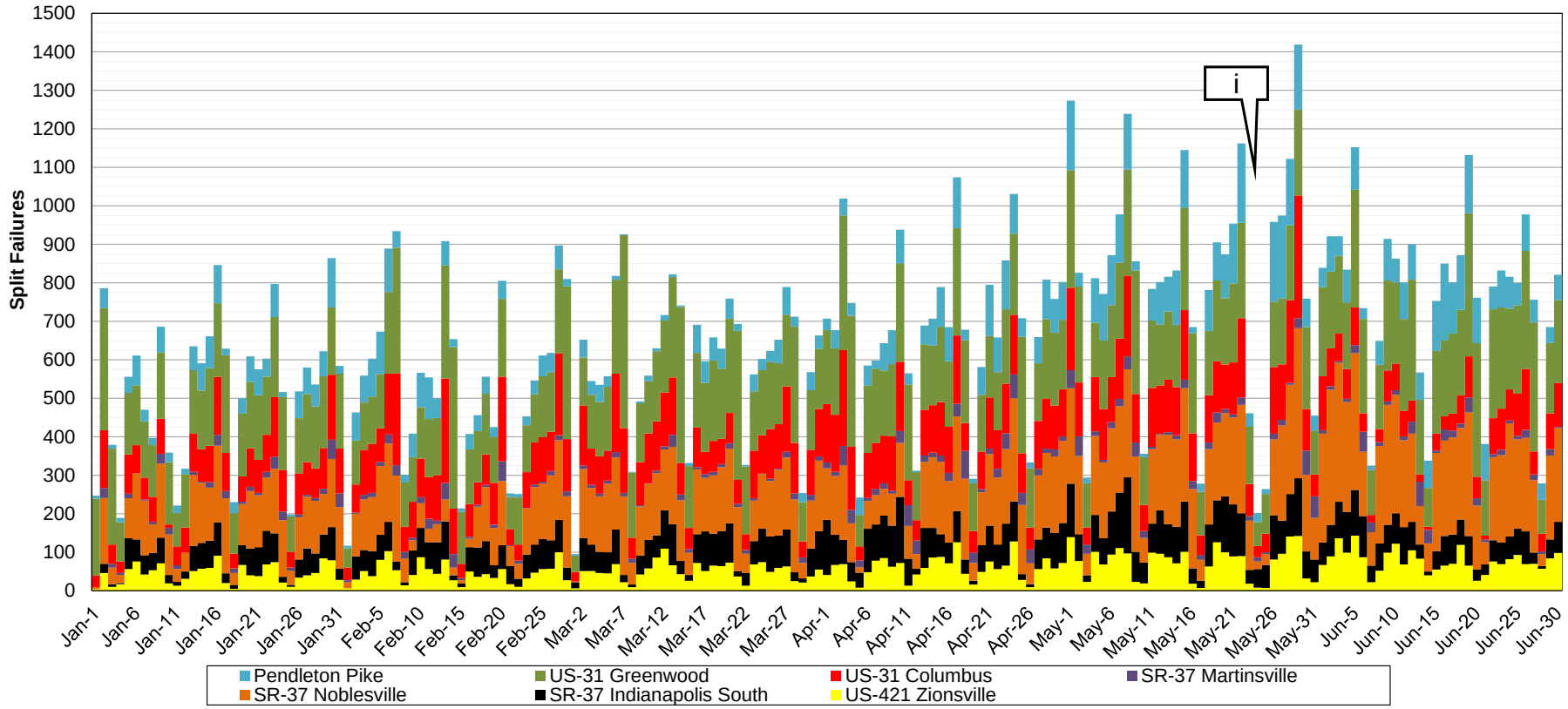


Indiana Corridor Selection

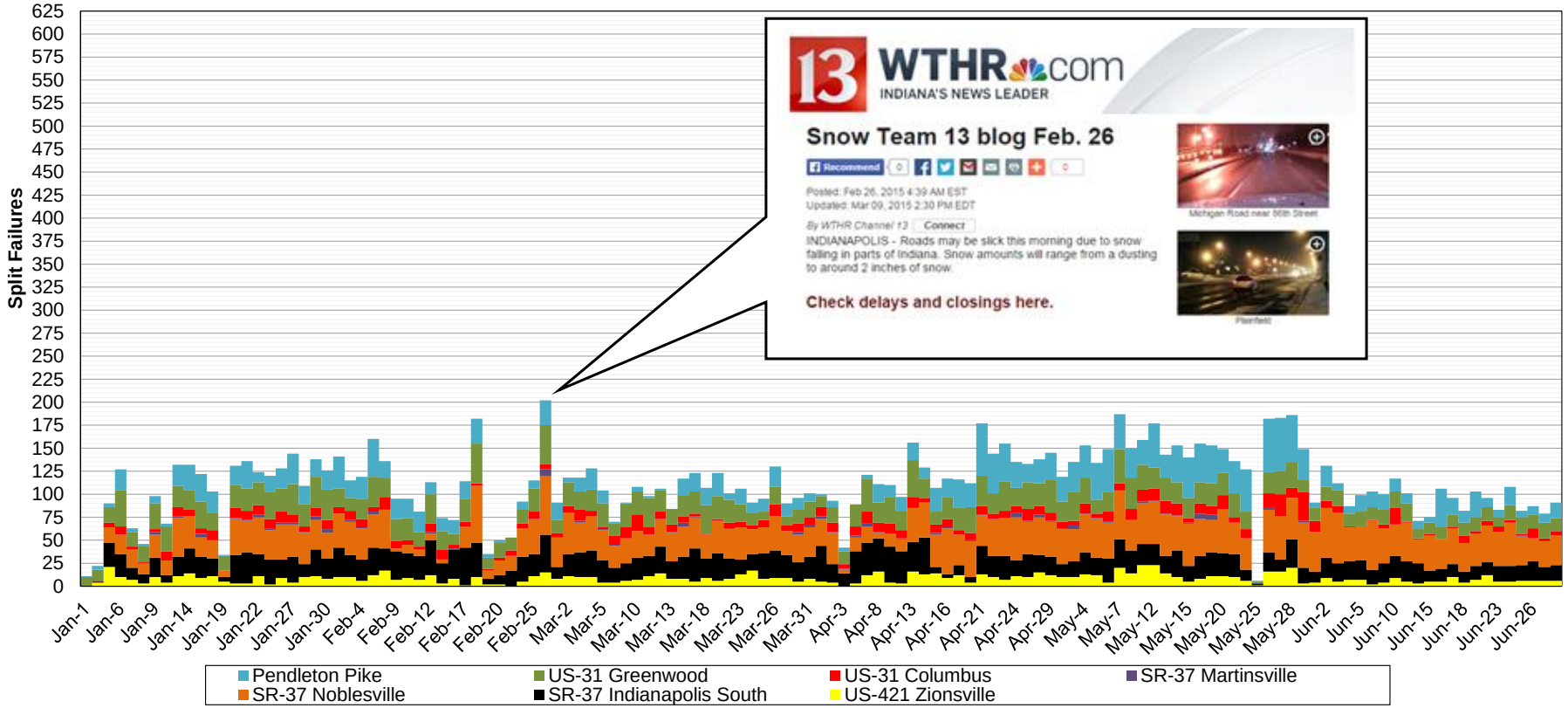


Corridor	Intersections	Phases	Lanes	Detectors
Pendleton Pike	14	133	192	208
US-31 Greenwood	11	93	141	139
US-31 Columbus	10	95	132	133
SR-37 Martinsville	5	39	53	75
SR-37 Noblesville	10	99	137	139
SR-37 Indianapolis South	13	99	151	162
US-421 Zionsville	7	79	101	117
Total	**70**	**637**	**907**	**973**

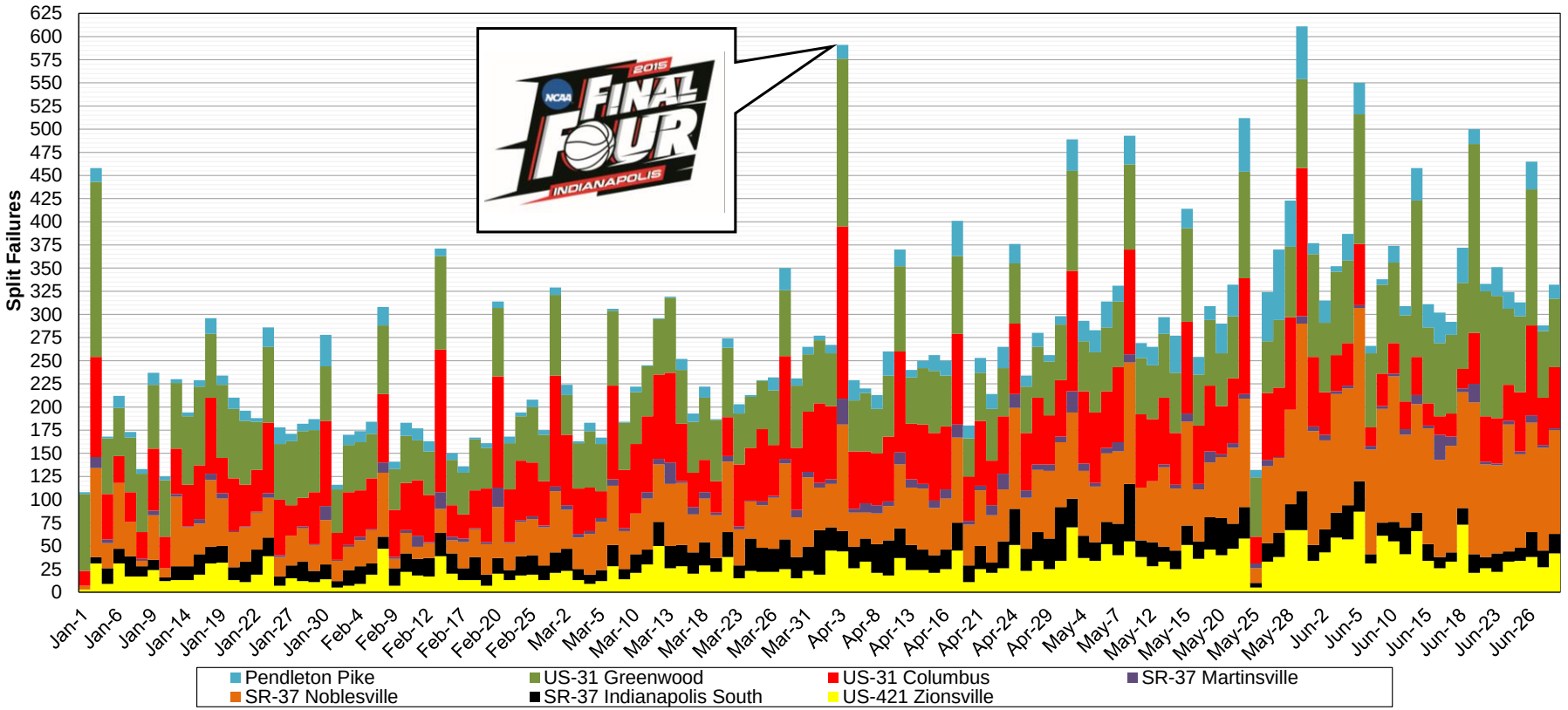
Top Level View



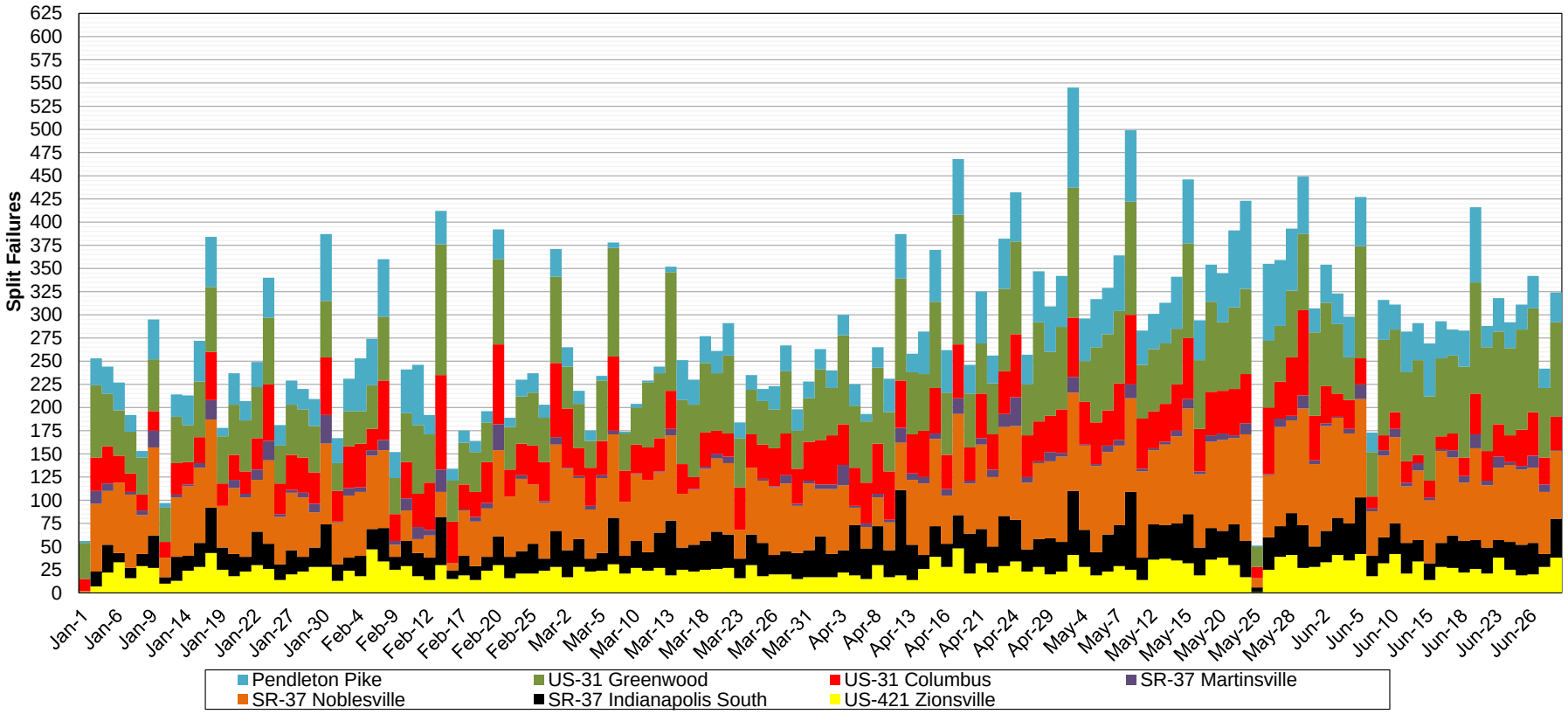
Segmentation by Time of Day:
Looking Only at the AM Peak (0600-0900)



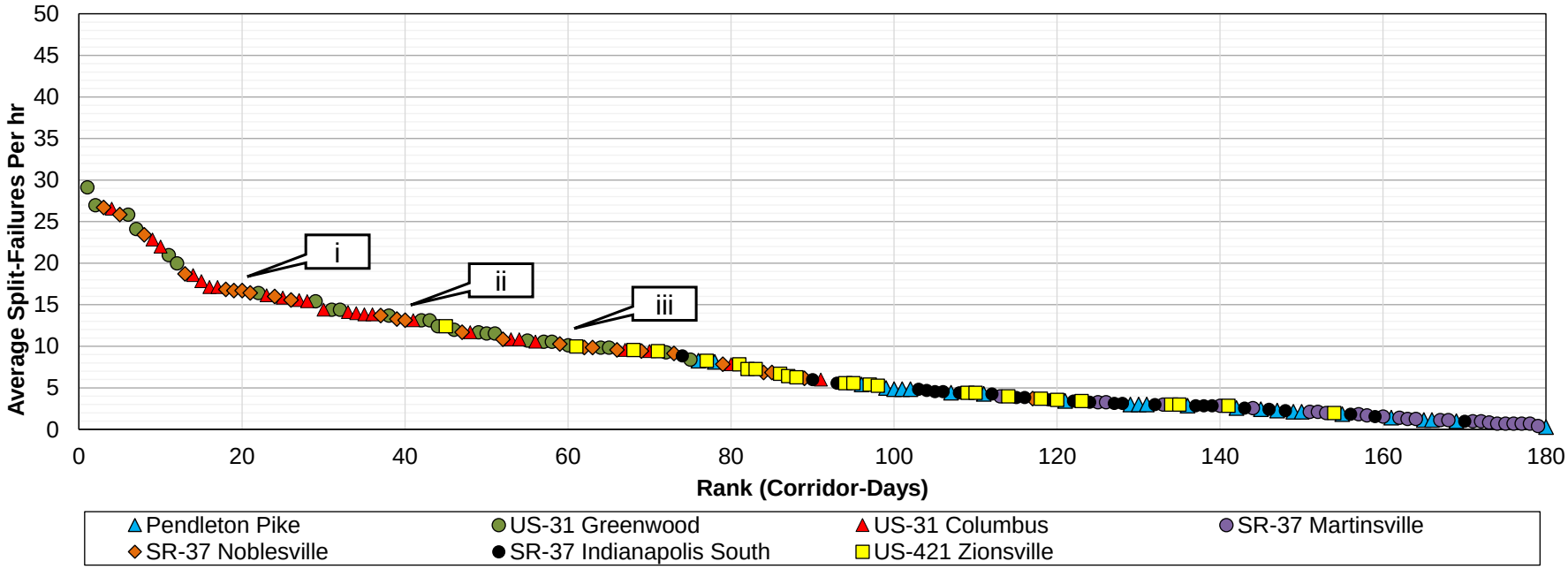
Segmentation by Time of Day:
Looking Only at the Midday (0900-1600)



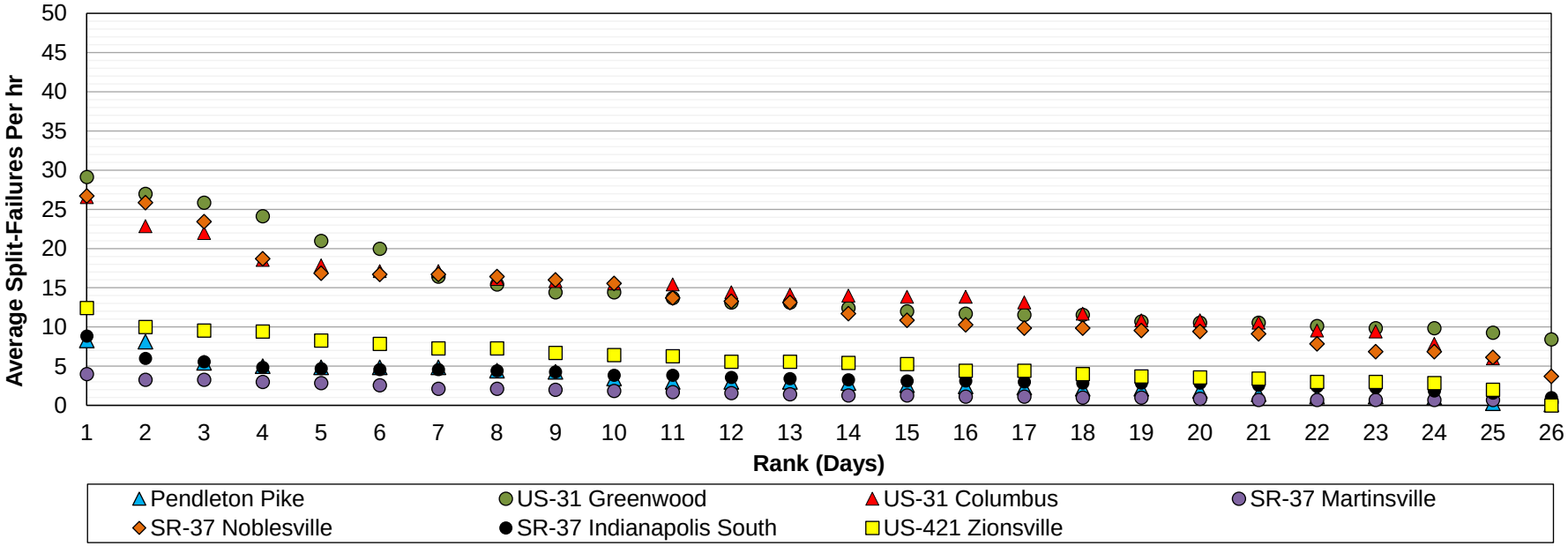
Segmentation by Time of Day:
Looking Only at the AM Peak (1600-1900)



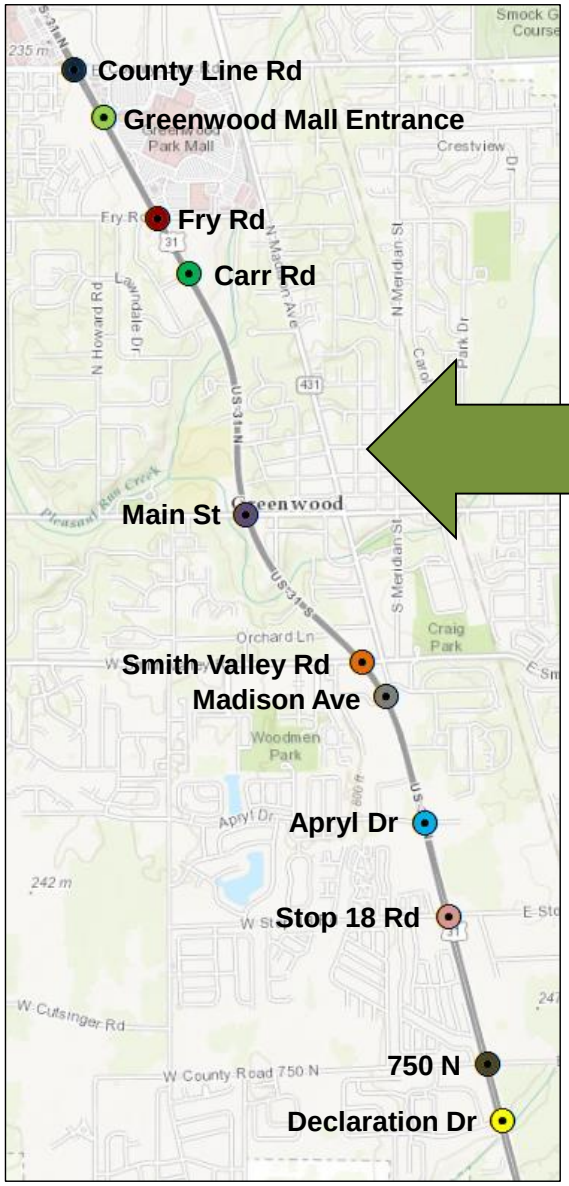
Friday Split Failures by Corridor / Date
Ranked Across the Entire System as Single List

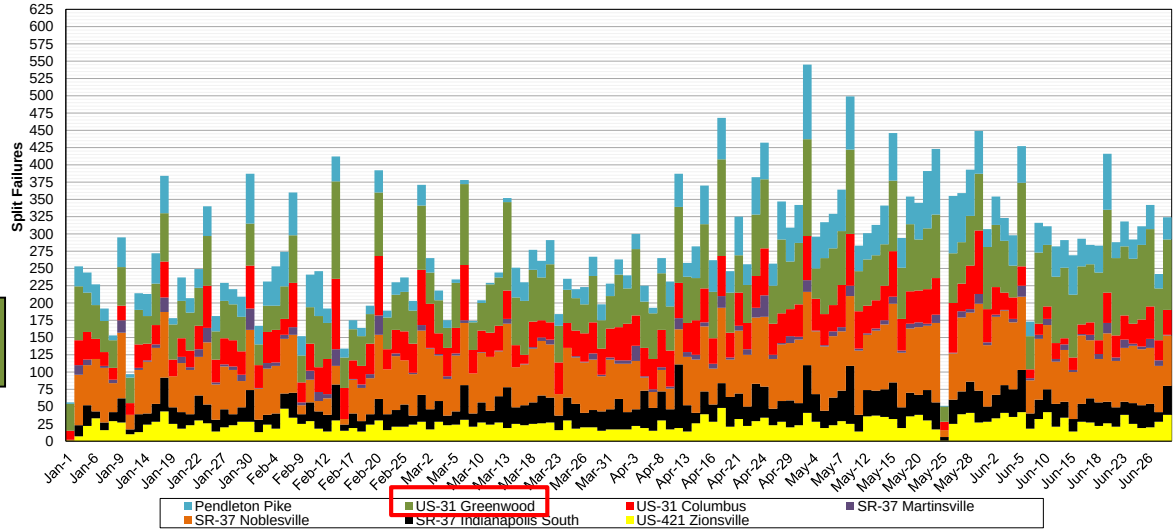


Friday Split Failures by Corridor
Worst Days of Each Corridor Ranked Separately

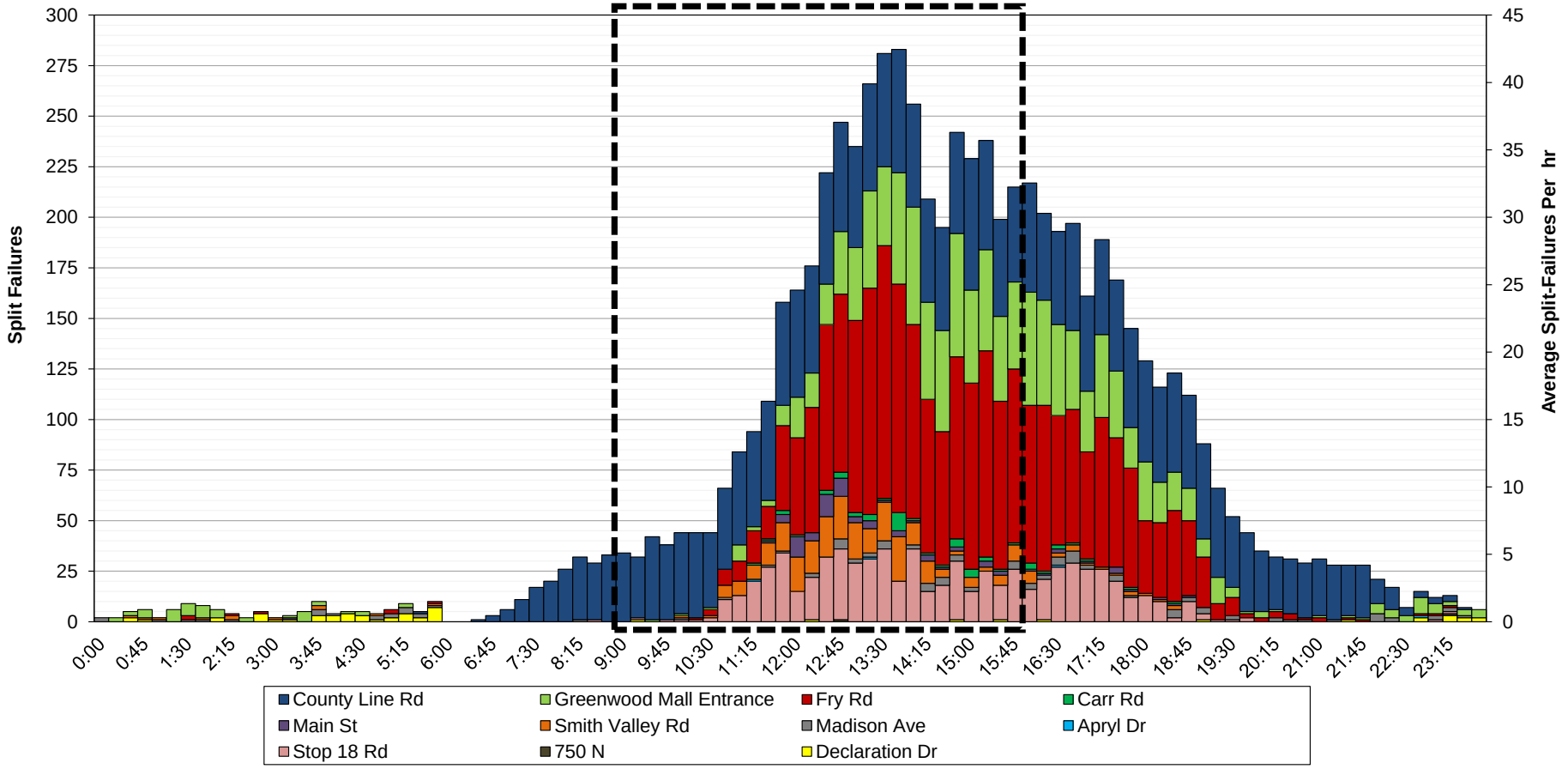


Drill down to Corridor… (US 31 Greenwood)

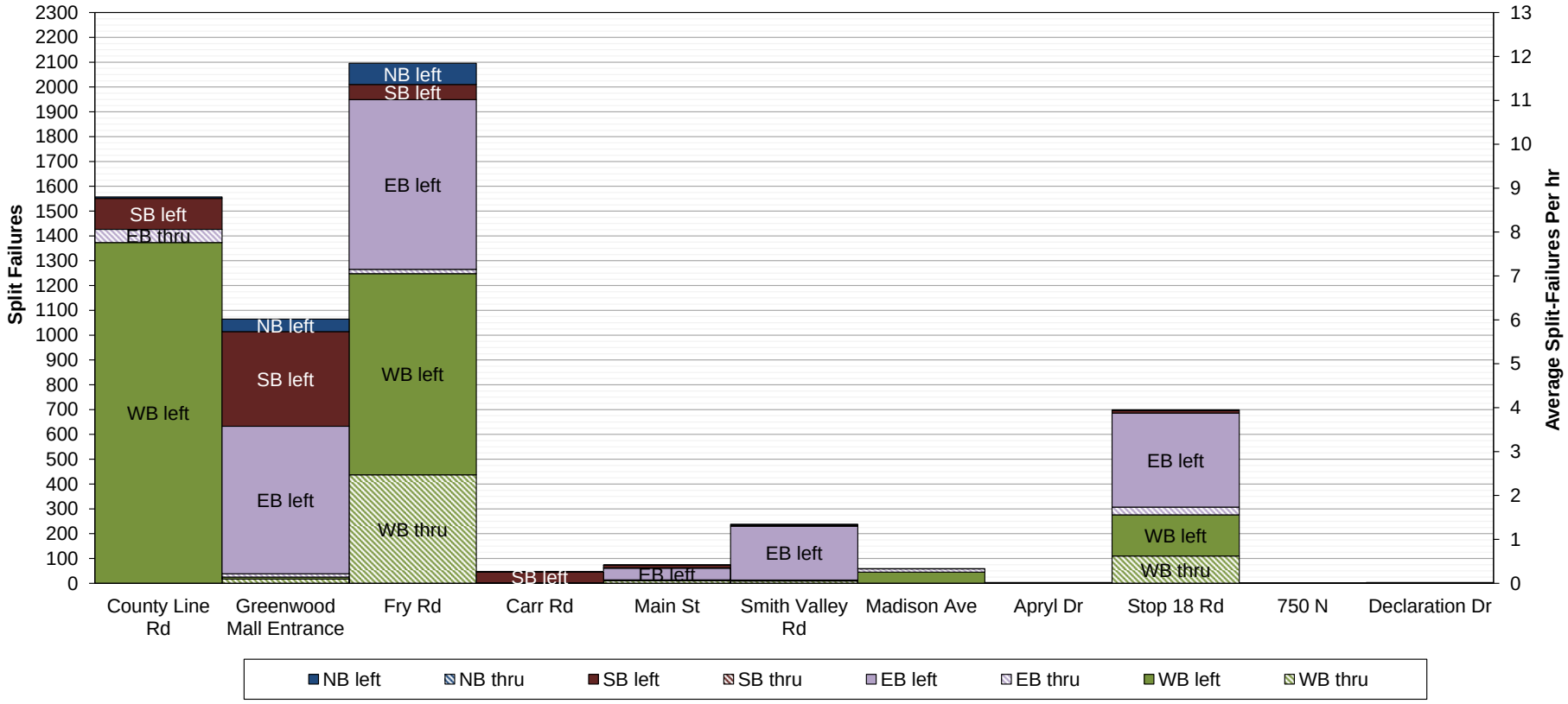




Split Failure Count
Corridor View by Intersection by Time of Day



Split Failure Count
Corridor View by Movement by Intersection



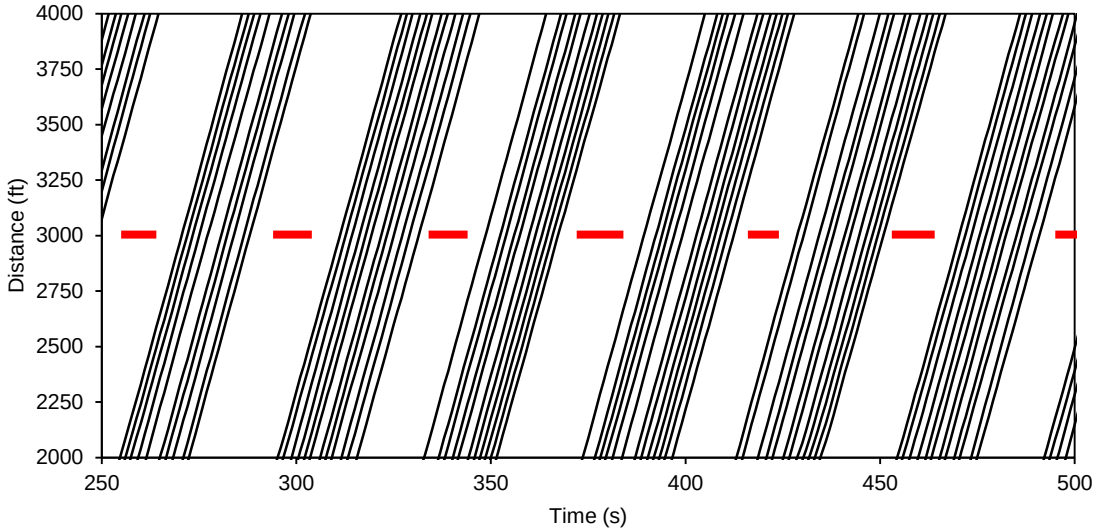
Top Level View: Executive Report
Average Number of Split Failures per Hour

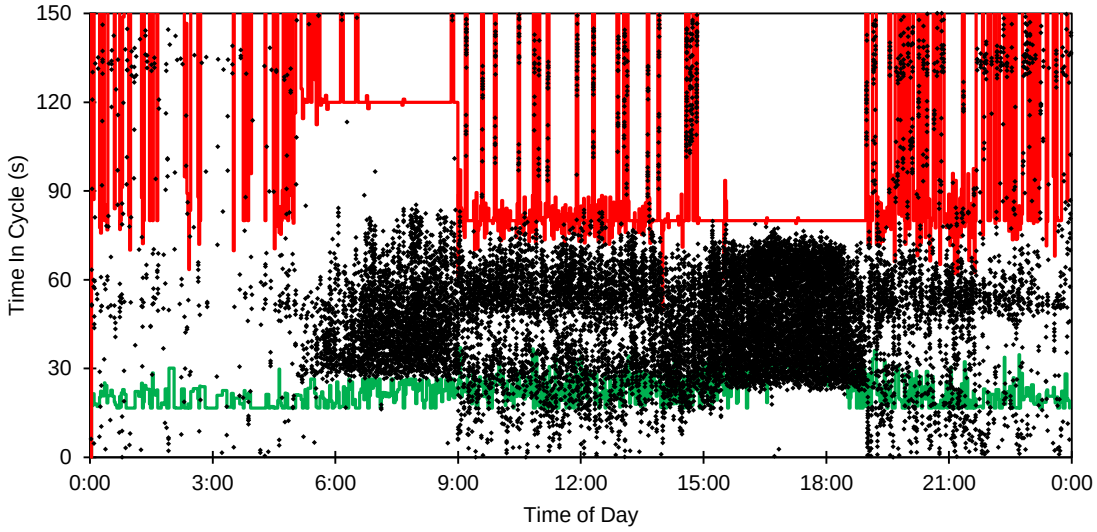
Corridor	Time of Day	Mon-Thur	Fri	Sat	Sun
Pendleton Pike	0600-0900	0.52	0.44	0.04	0.06
	0900-1600	0.65	0.23	0.17	0.08
	1600-1900	1.49	1.17	0.12	0.08
US-31 Greenwood	0600-0900	0.67	0.60	0.21	0.08
	0900-1600	0.83	1.35	2.22	0.89
	1600-1900	1.89	2.99	2.28	0.70
US-31 Columbus	0600-0900	0.25	0.26	0.04	0.02
	0900-1600	0.76	1.43	0.94	0.39
	1600-1900	1.21	1.86	0.73	0.33
SR-37 Martinsville	0600-0900	0.06	0.07	0.02	0.01
	0900-1600	0.12	0.34	0.69	0.40
	1600-1900	0.28	1.05	0.26	0.12
SR-37 Noblesville	0600-0900	1.08	0.93	0.06	0.03
	0900-1600	0.83	1.33	1.72	0.47
	1600-1900	2.21	2.98	0.83	0.21
SR-37 Indianapolis South	0600-0900	0.58	0.48	0.04	0.05
	0900-1600	0.22	0.28	0.14	0.07
	1600-1900	0.70	1.12	0.32	0.07
US-421 Zionsville	0600-0900	0.42	0.33	0.06	0.05
	0900-1600	0.52	0.84	0.44	0.16
	1600-1900	1.14	1.35	0.25	0.16

Messages

1. Web dissemination
2. Background/Context/Attribution
3. Performance Measure Pyramid
   - Communication
   - Detectors
   - Splits
   - **Coordination**
4. Longitudinal System Monitoring
5. Outcome Assessment Telling Our Story
6. Performance Measures will not reduce consulting, but I believe their services will evolve

Very Good Progression…





Messages

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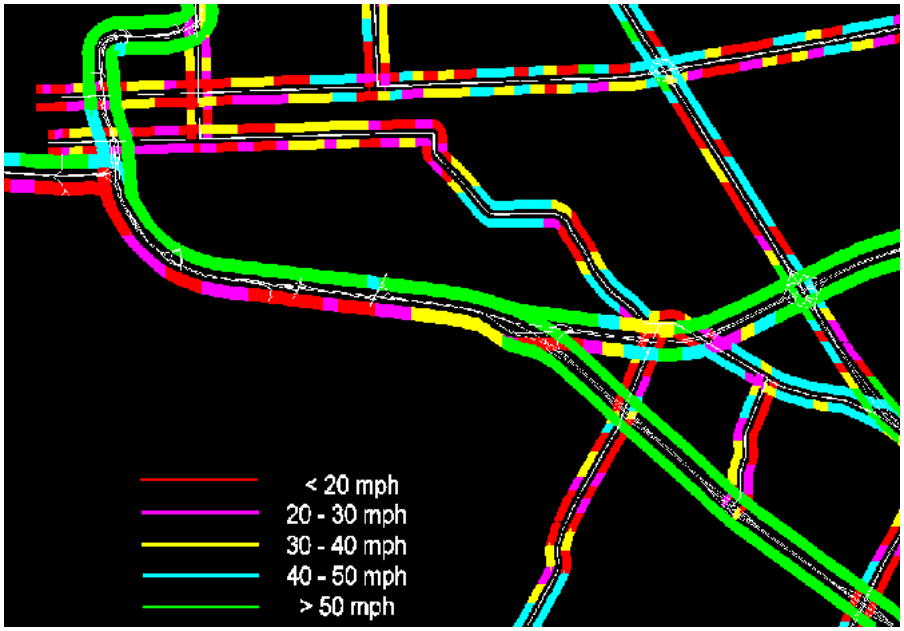
4. **Longitudinal System Monitoring**
5. **Outcome Assessment Telling Our Story**
6. Performance Measures will not reduce consulting, but I believe their services will evolve

Probe Vehicle Data, the Early years

Graduate Student Powered (circa 1994)

PURDUE UNIVERSITY



DB students drove 25,000 miles in BTR in 1990's

LSU

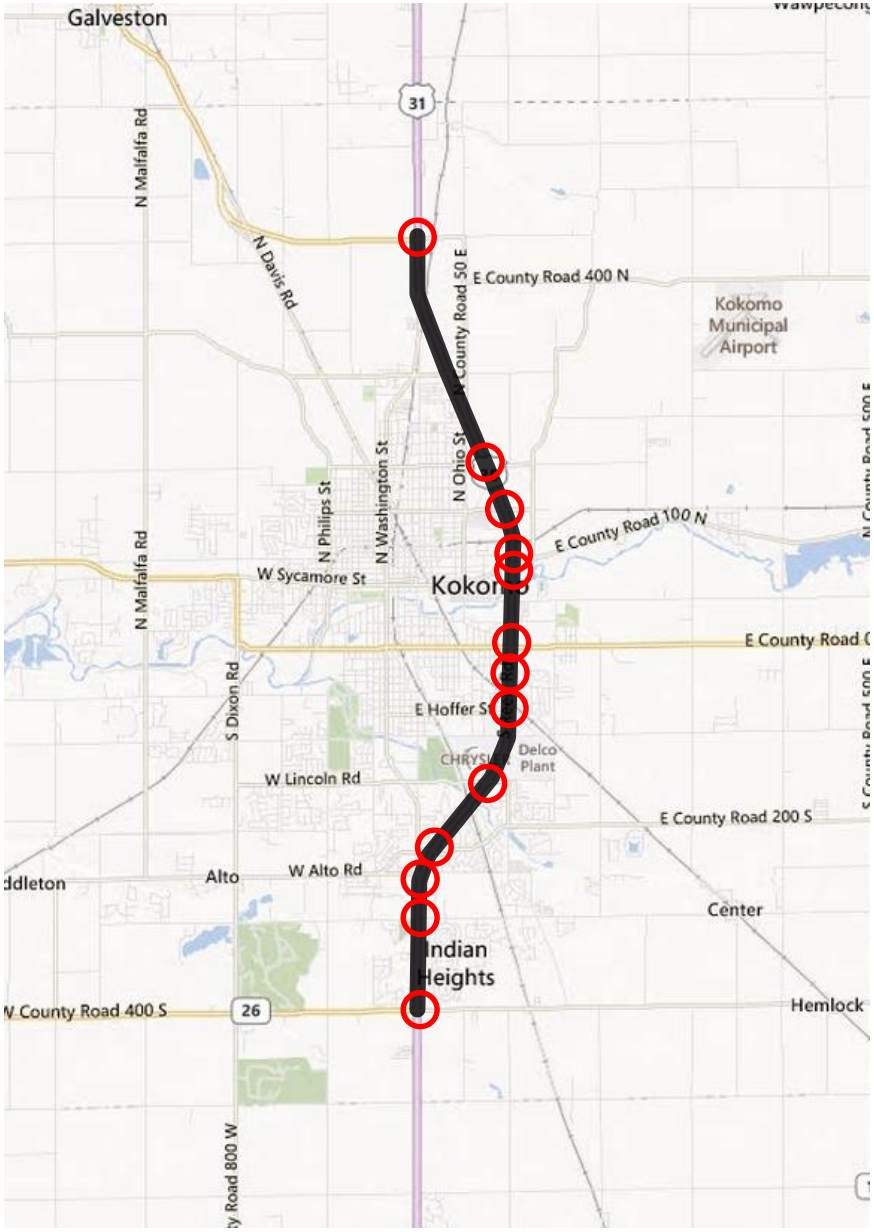
Circa 2009 Probe Monitoring Stations in Indiana

Long Term Installation with Real-Time SQL Based Travel Time Calc

Short Term Battery Powered Device (Traffax)..Data post processed

Short Term Installation with Real-Time SQL Based Travel Time Calc

US 31 in Kokomo, Indiana



- 9 Mile Arterial Between Indianapolis and South Bend.
- 13 Signals Retimed during the first week of April in 2012

Before Retiming

Week 13

MARCH 2012

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	31

Retiming

Week 15

Week 16

After Retiming

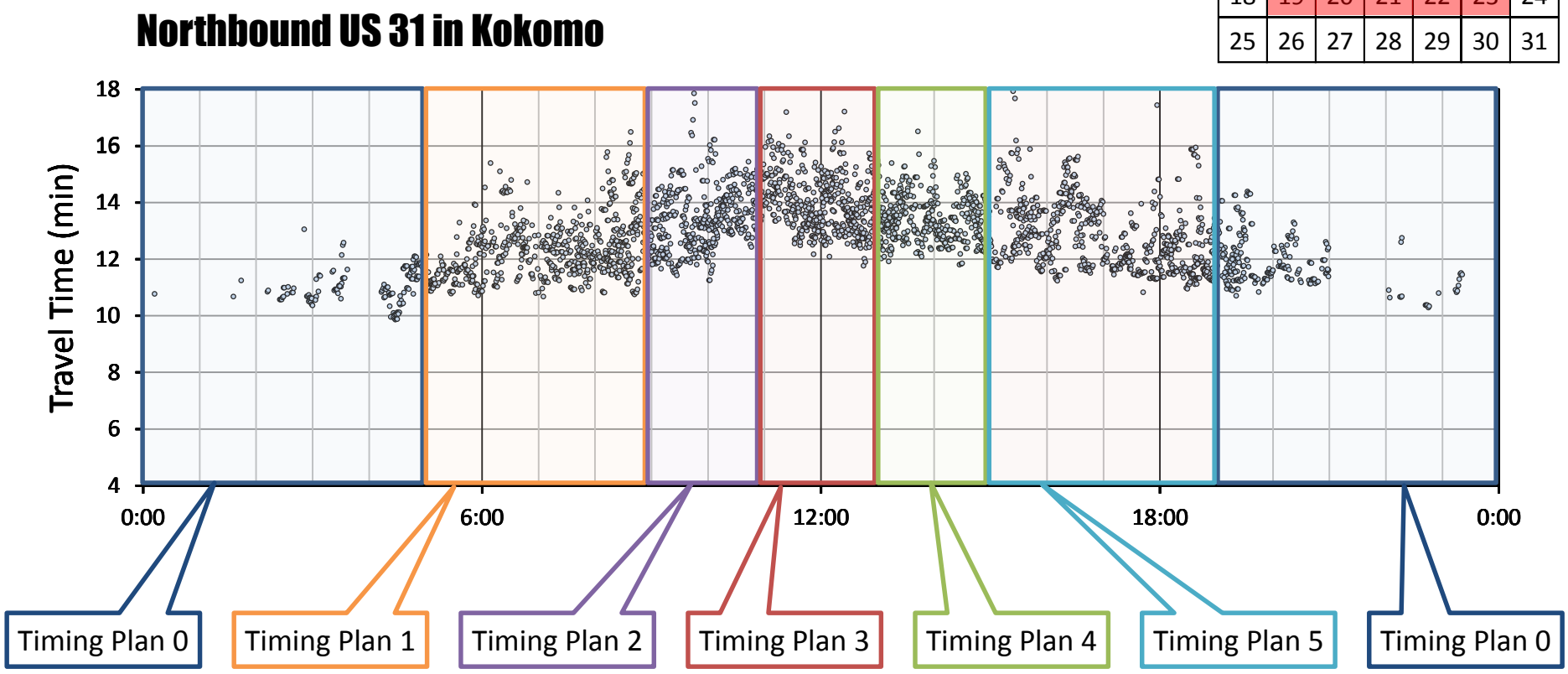
APRIL 2012

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					

Data Representation

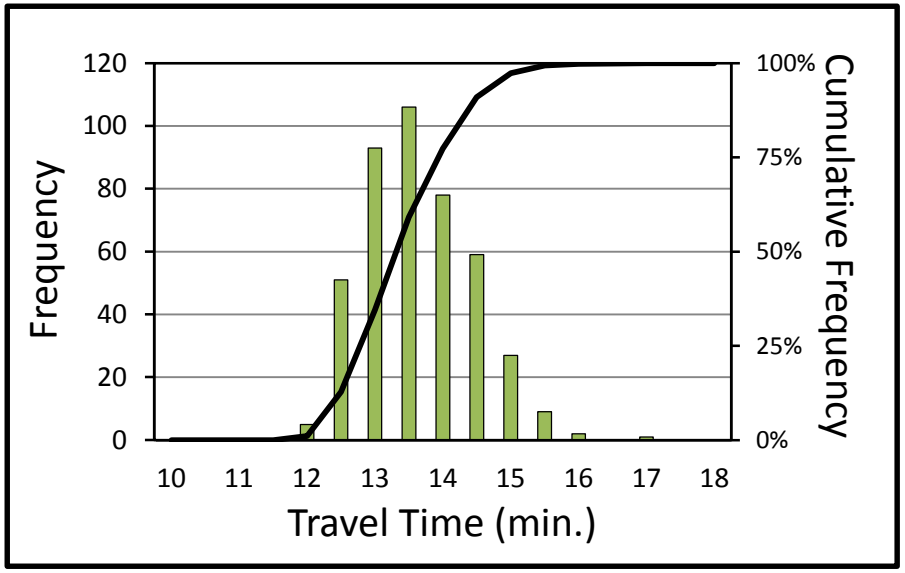
Cumulative Frequency Diagram

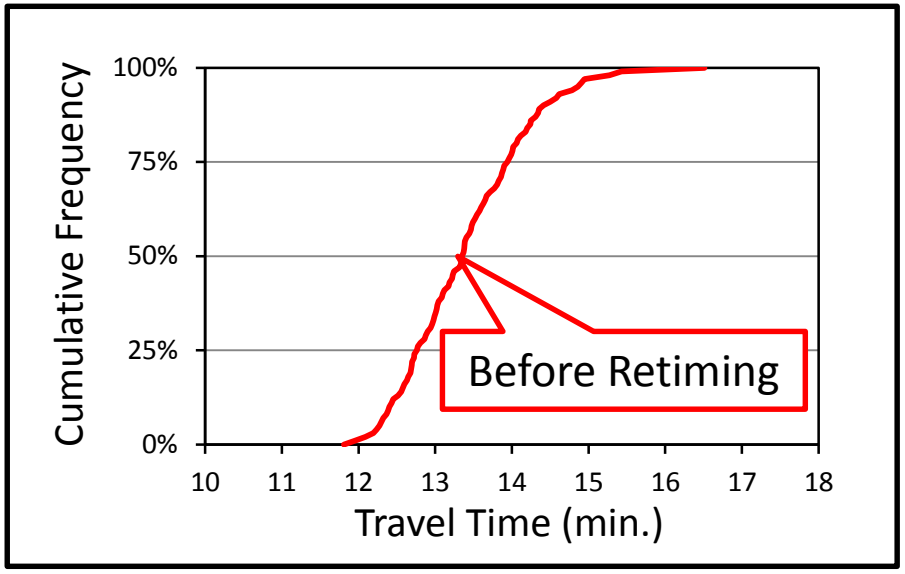
MARCH 2012						
S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

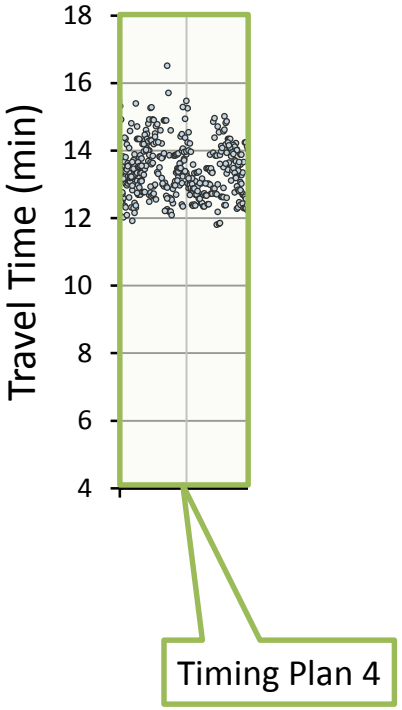


Data Representation

Cumulative Frequency Diagram







MARCH 2012						
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
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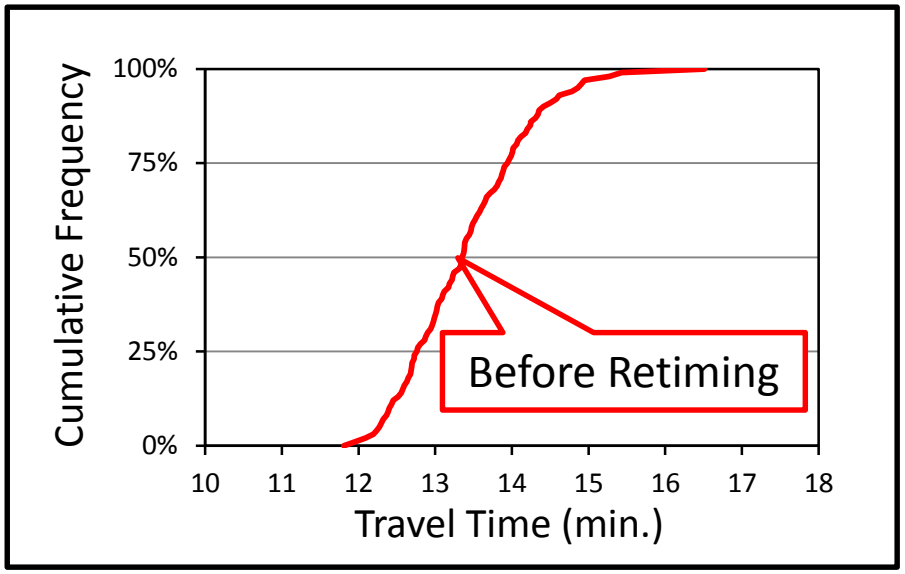
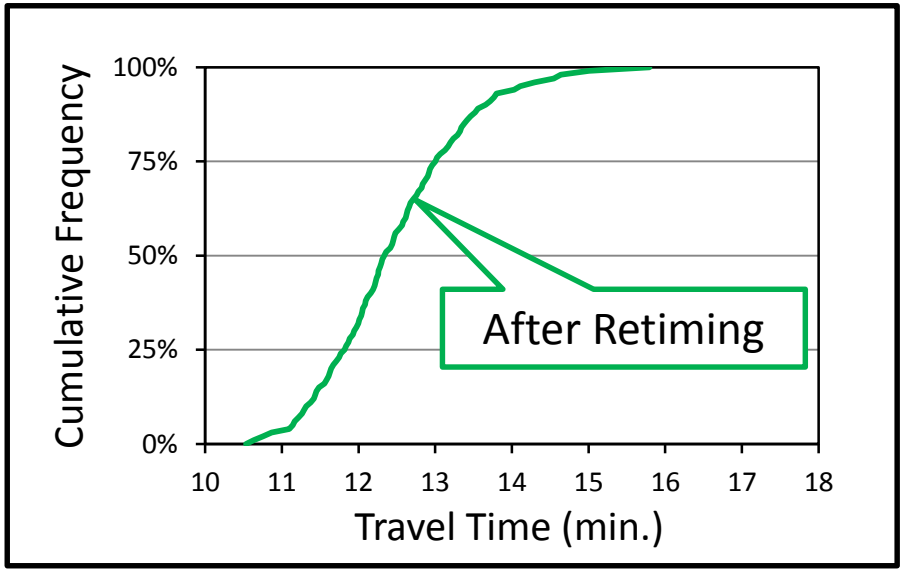
Data Representation

Cumulative Frequency Diagram





Retiming Week

MARCH 2012						
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	31

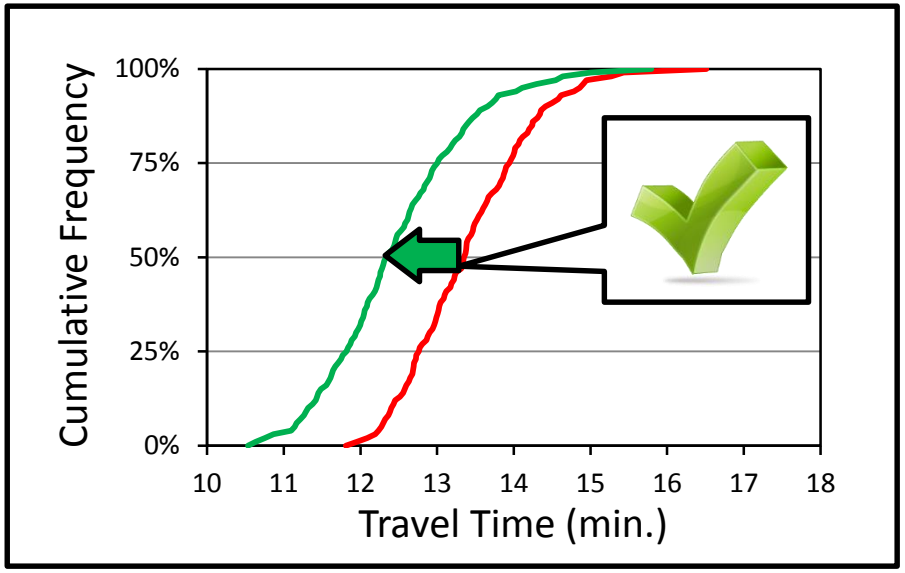
APRIL 2012						
S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

Data Representation

Cumulative Frequency Diagram

MARCH 2012						
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	31

APRIL 2012						
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					



1 Minute Reduction

Arterial Retiming Analysis

Kokomo, Indiana

MARCH 2012						
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	31

Before Retiming

Week 13

APRIL 2012						
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
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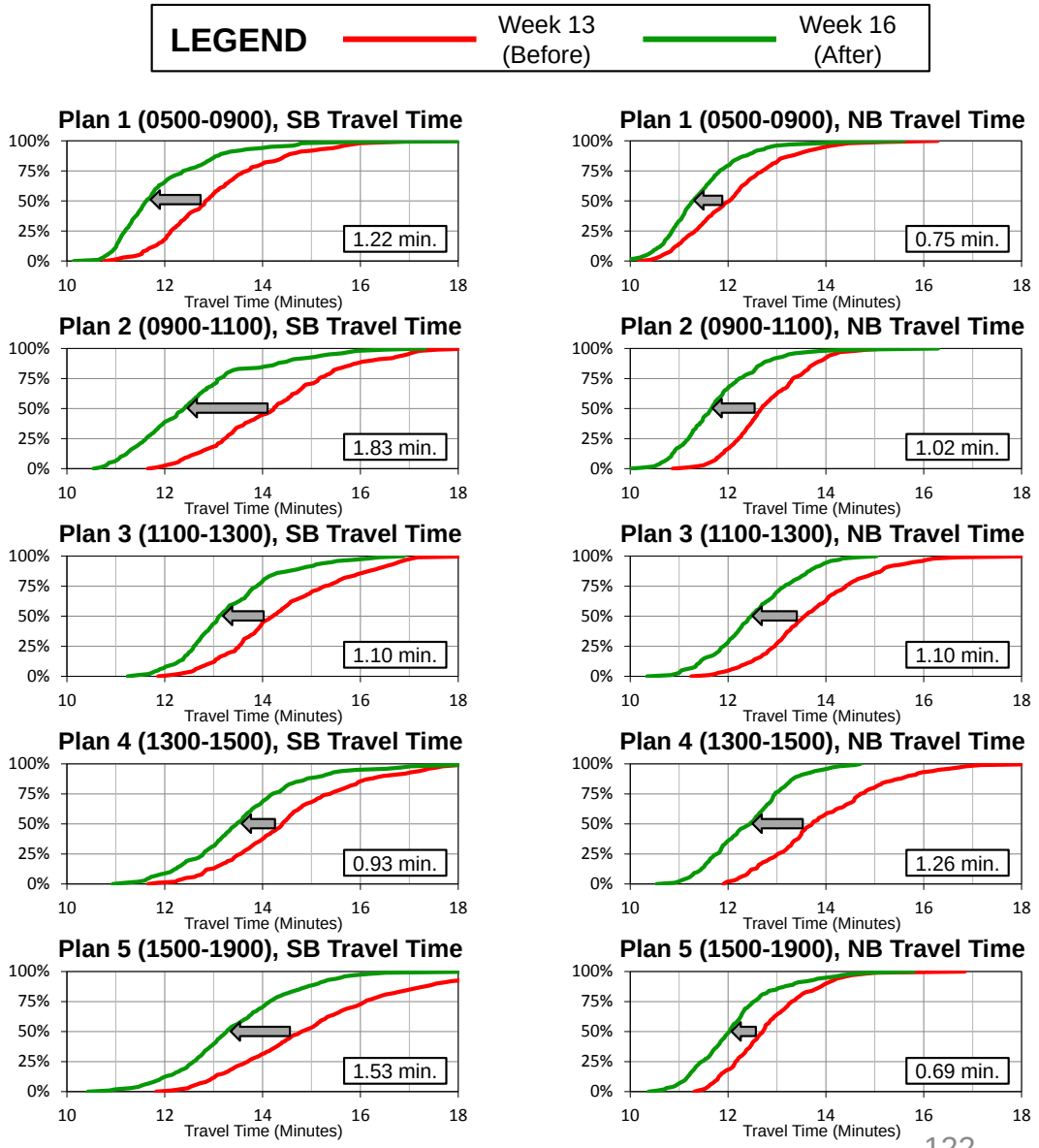
Retiming

Week 15

Week 16

After Retiming



Probe Data Analysis

Creating performance measures from large datasets

Kokomo Signal Retiming

TRAVEL TIME ASSESSMENT PROCESS

Select Corridor from Indiana corridor list

Corridor (left pane): US-31 Kokomo SB
Corridor (right pane): US-31 Kokomo NB
OK

24 one-hour periods
24 one-hour periods

US-30 EB
US-30 WB
US-31 Carmel NB
US-31 Carmel SB
US-31 Kokomo NB
US-31 Kokomo SB
US-36 Avon EB
US-36 Avon WB
US-36 Pendleton Pike EB
US-36 Pendleton Pike WB
US-40 Washington St. EB
US-40 Washington St. WB
US-41 Indianapolis Blvd. NB
US-41 Indianapolis Blvd. SB
US-421 Michigan Rd. NB
US-421 Michigan Rd. SB
US-52 Brookville Rd. EB
US-52 Brookville Rd. WB
US-52 Lafayette EB
US-52 Lafayette WB

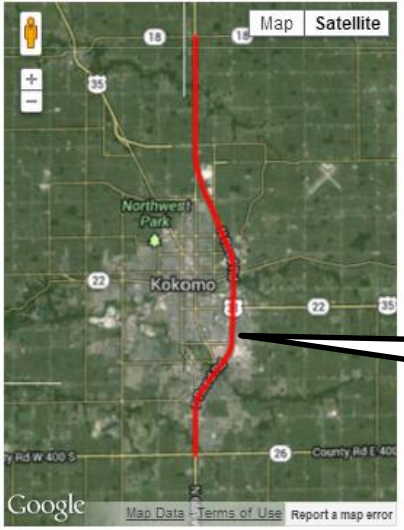
30 7 14 21 28 4

Sun

30 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

US-31 Kokomo SB

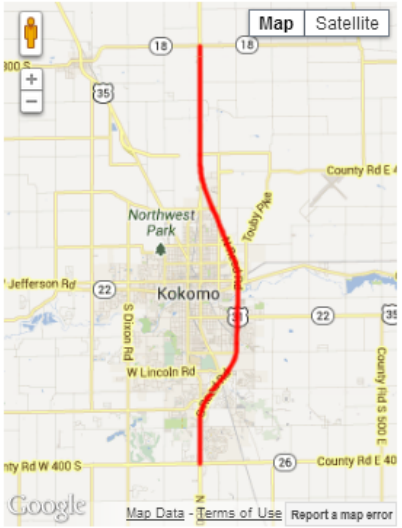
US-31 Kokomo NB



Selected Corridor will appear in map

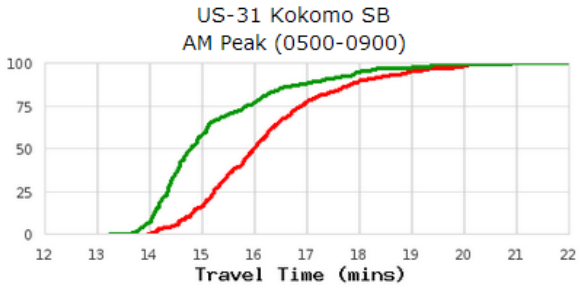
◄	July 2013					►
Sun	Mon	Tue	Wed	Thu	Fri	Sat
30	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31	1	2	3
4	5	6	7	8	9	10

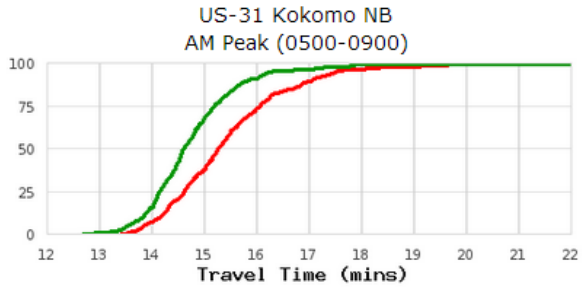
◄	July 2013					►
Sun	Mon	Tue	Wed	Thu	Fri	Sat
30	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31	1	2	3
4	5	6	7	8	9	10

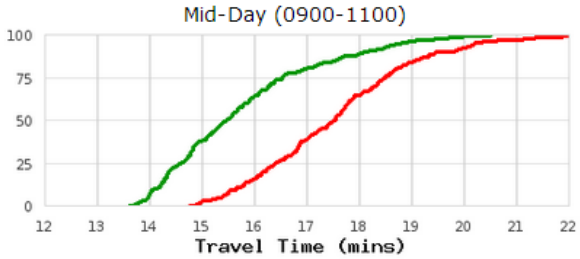


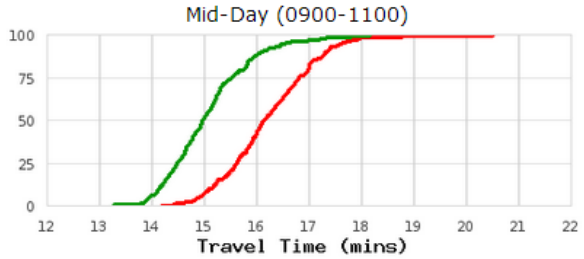
Before

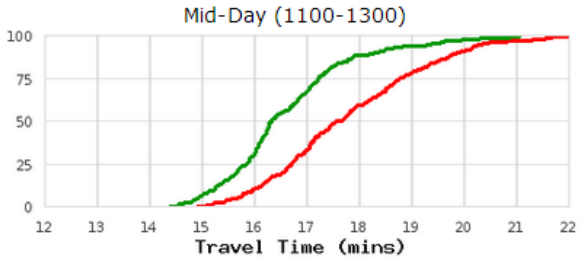
After

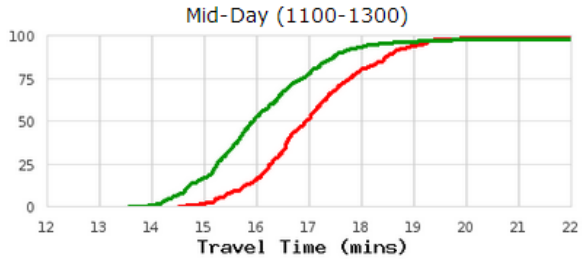


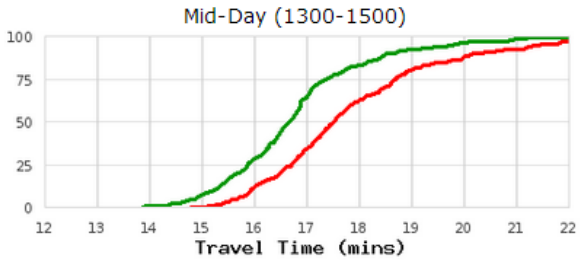


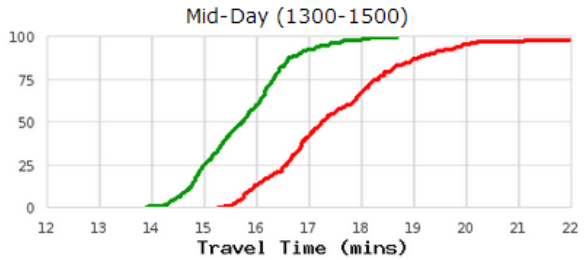


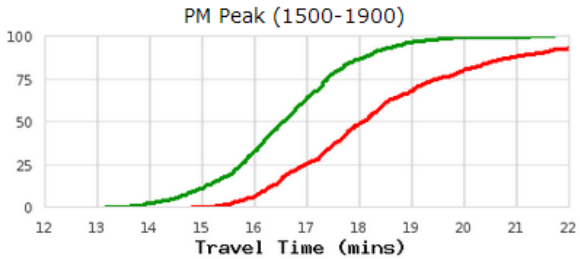


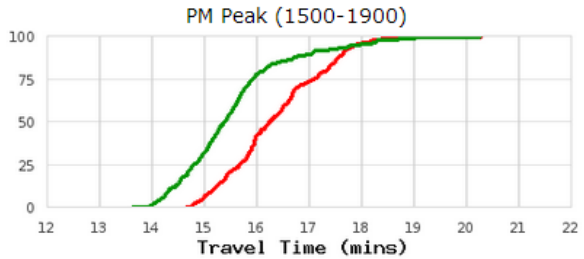


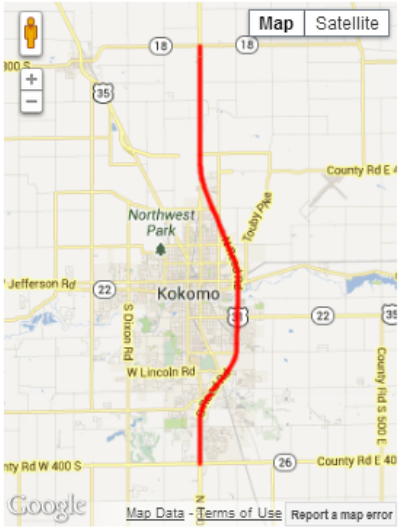












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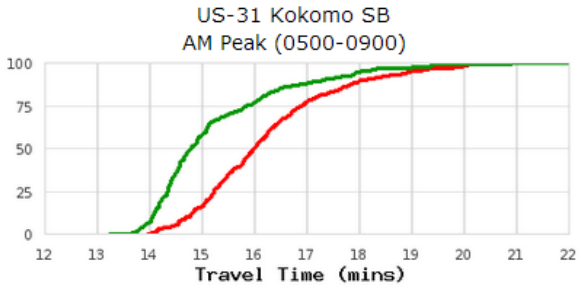
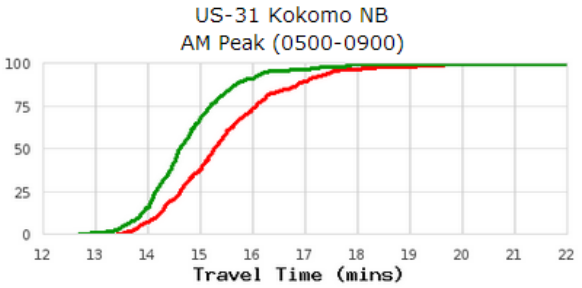
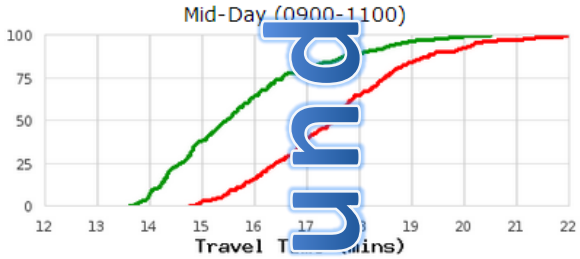
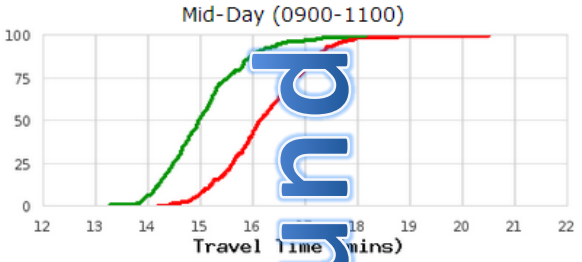
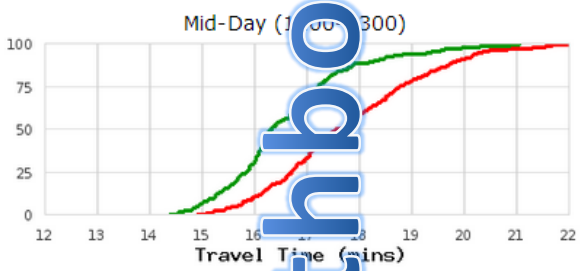
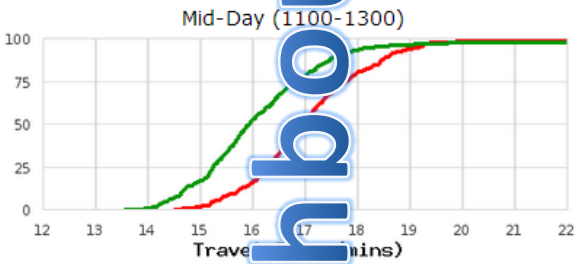


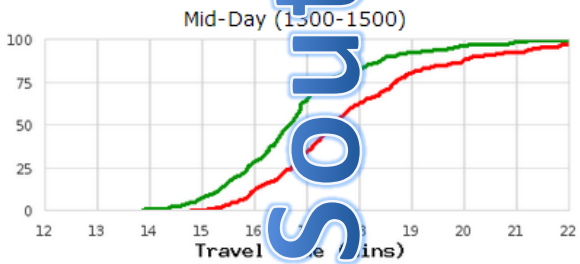


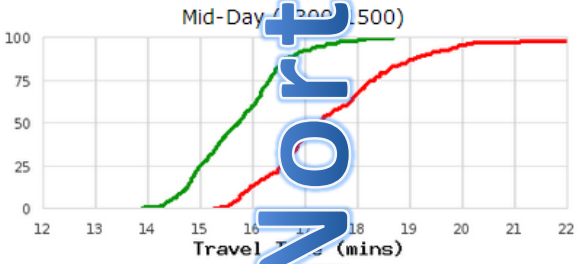


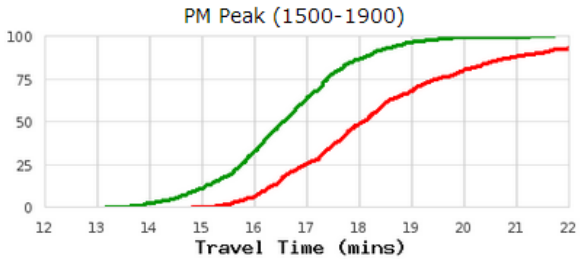


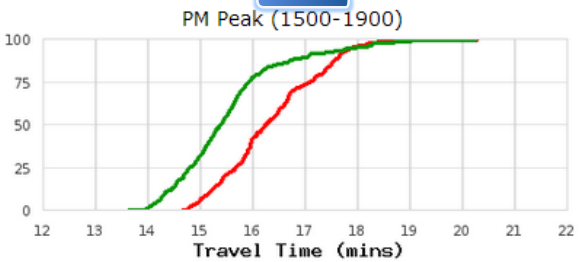






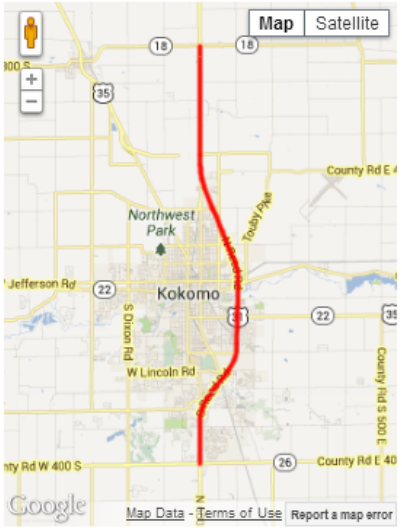


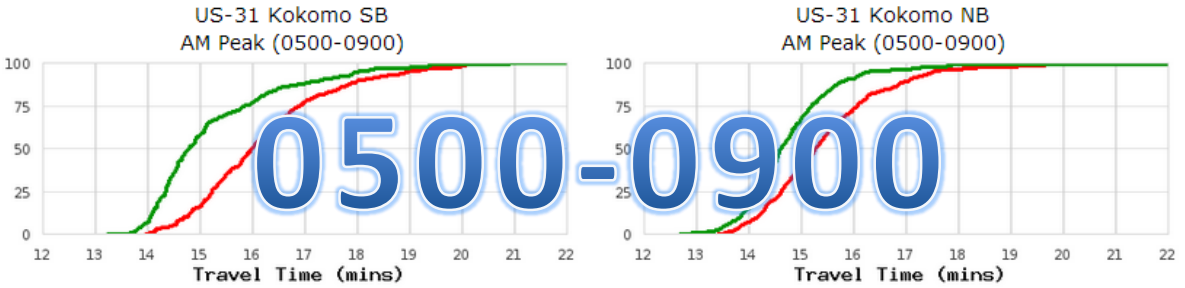


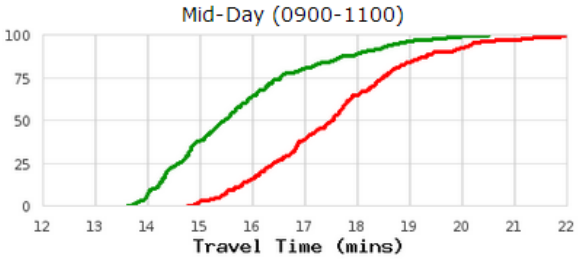


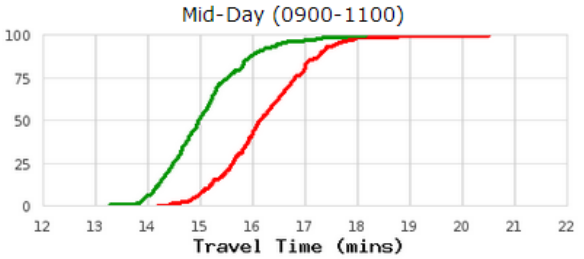
Southbound

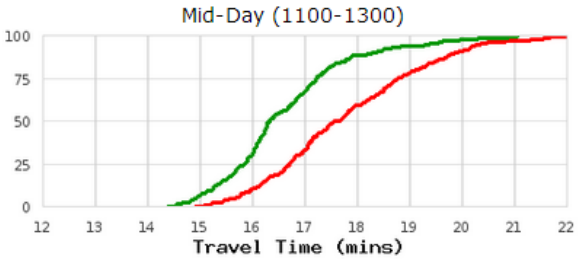
Northbound

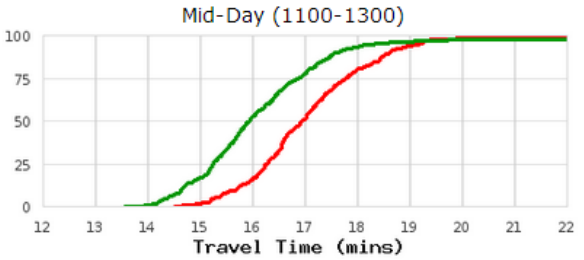


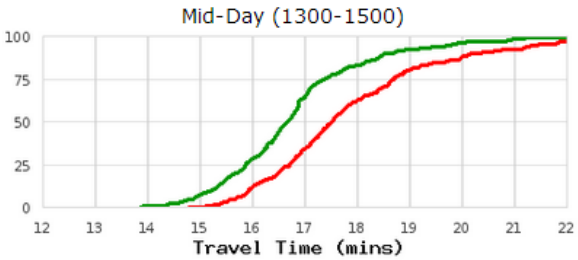


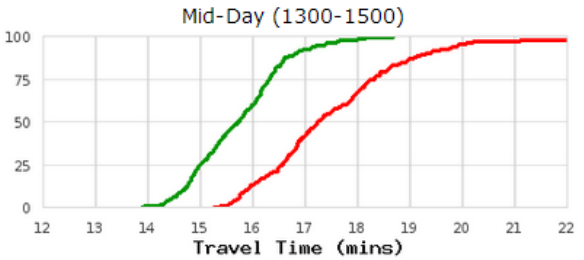


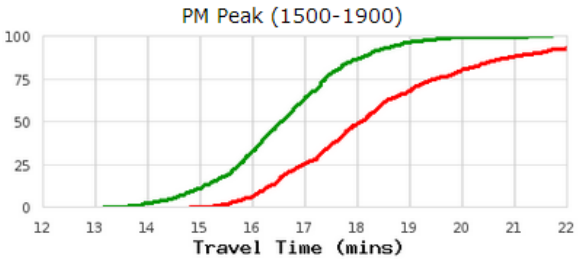


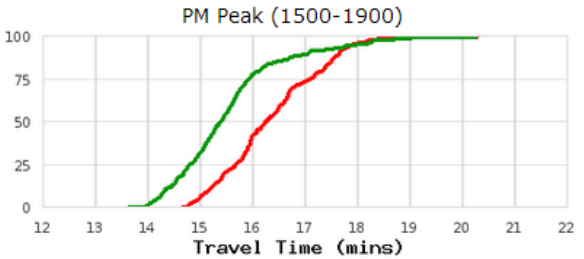












March 2012

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April 2012

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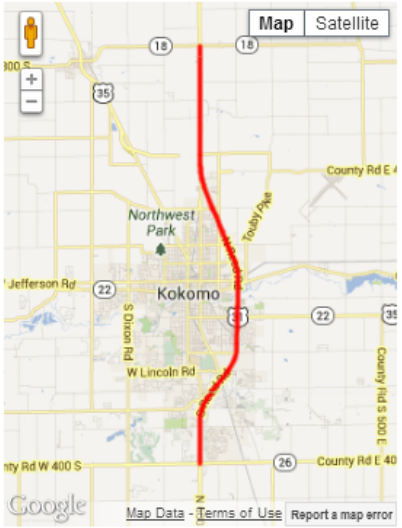

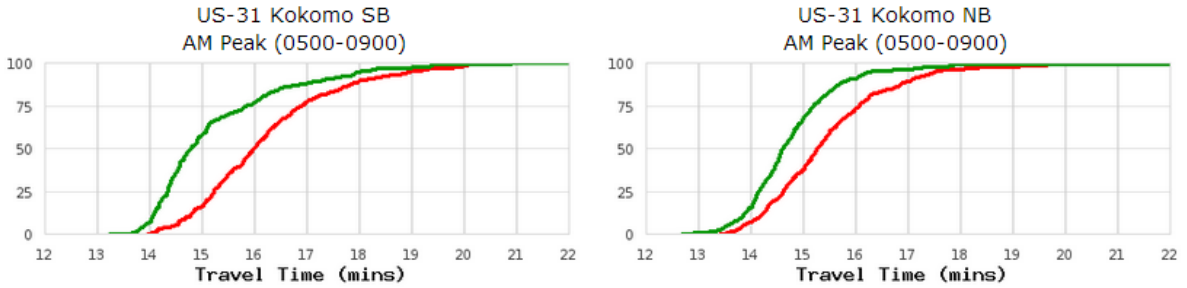

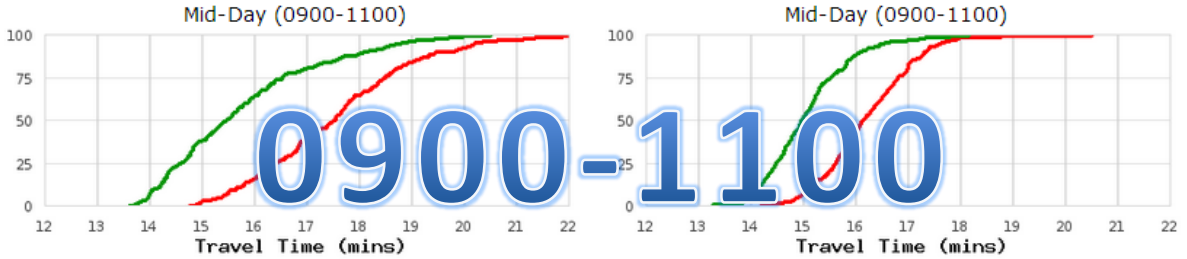

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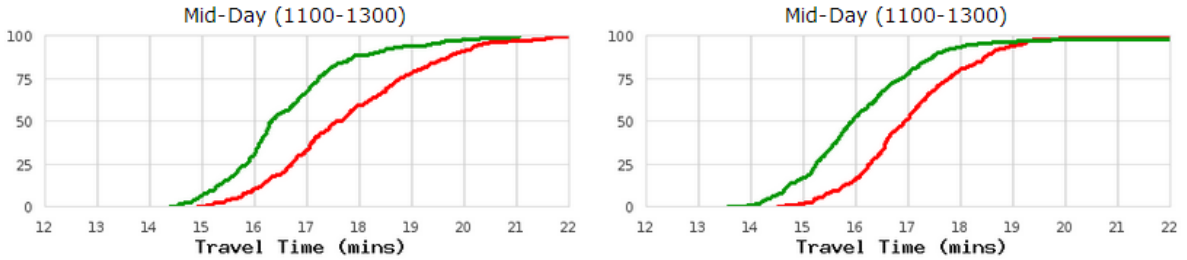

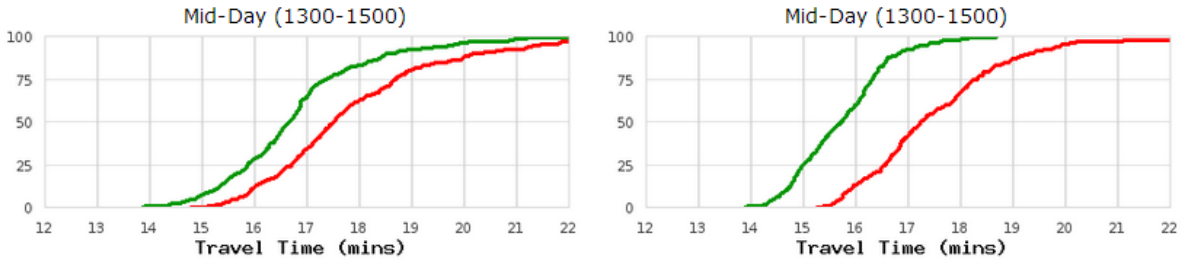

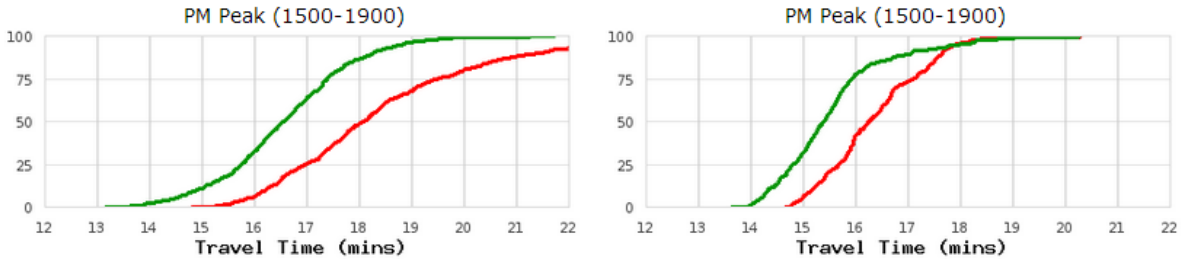

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April 2012

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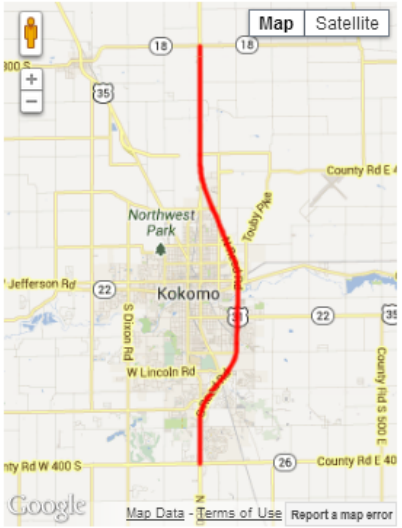

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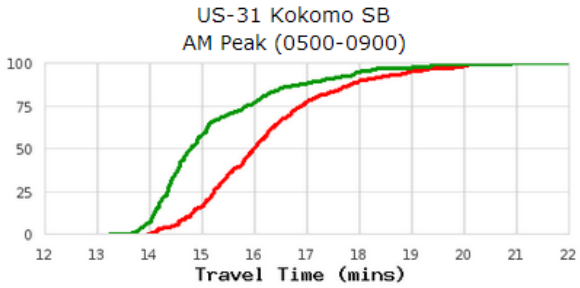

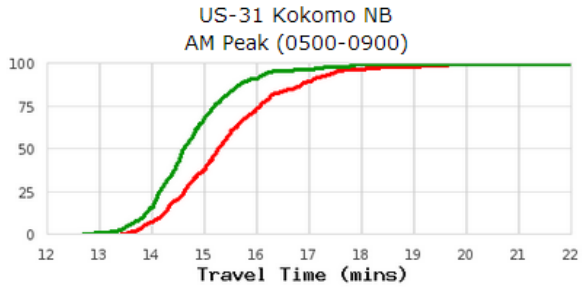

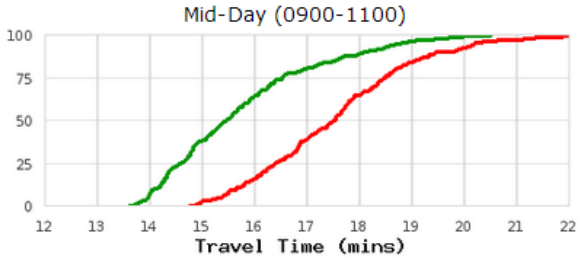

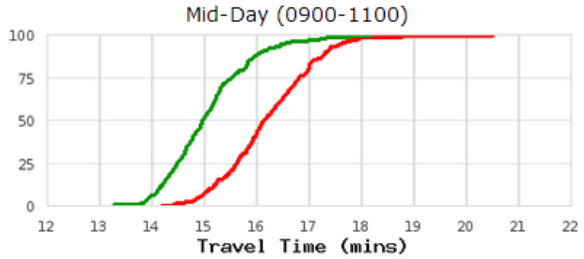

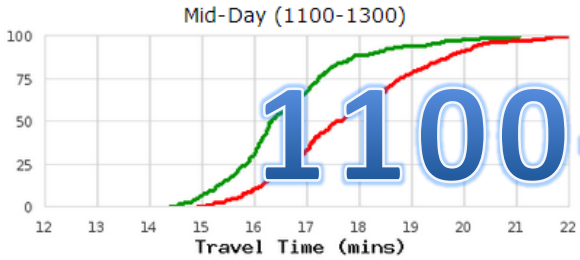

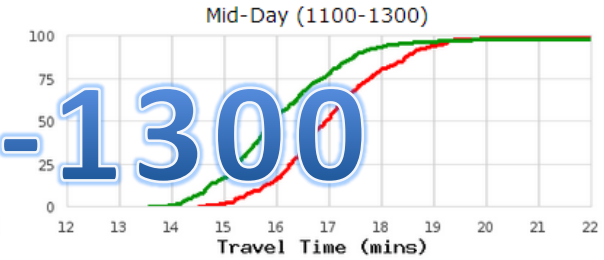

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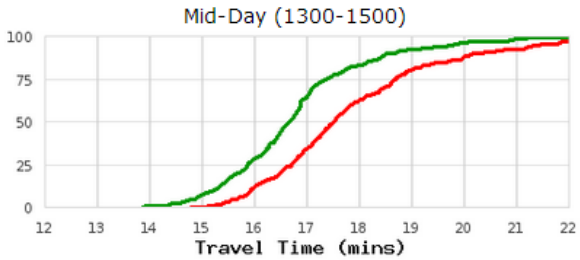

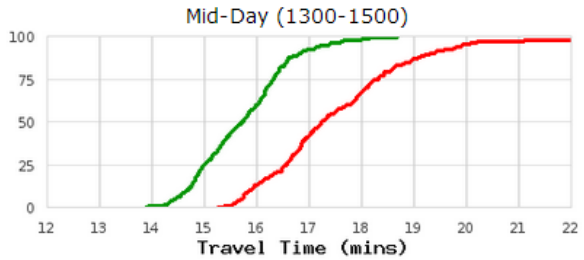

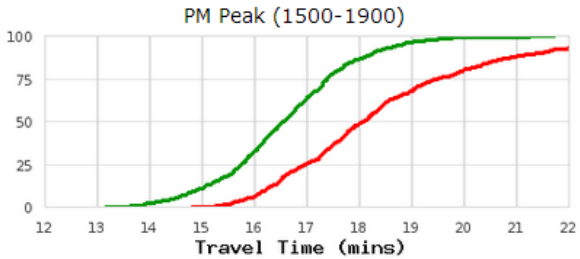

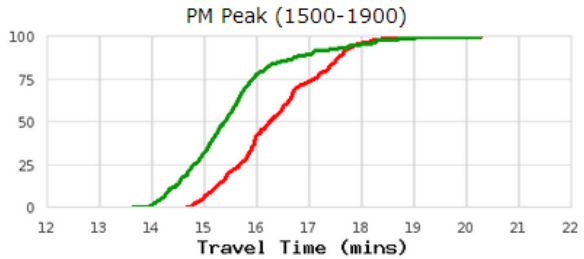

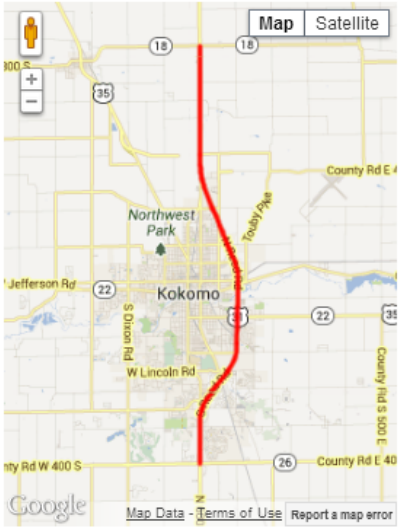

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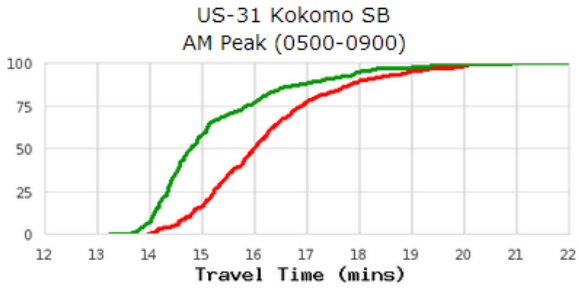

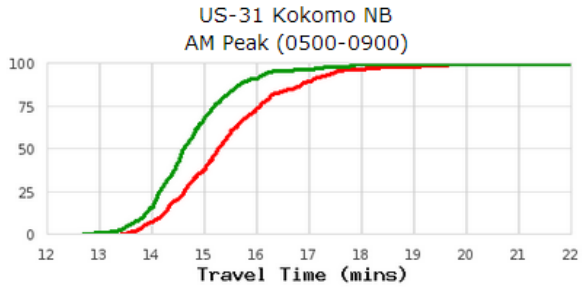

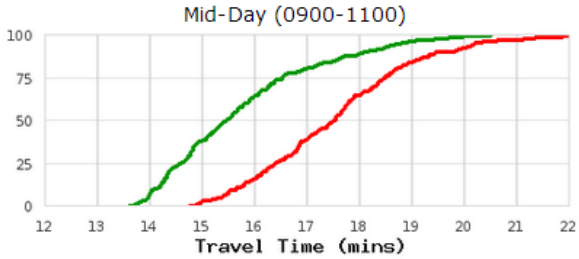

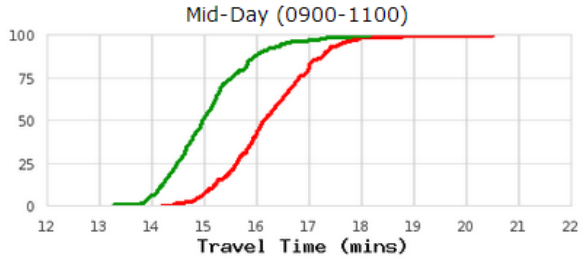

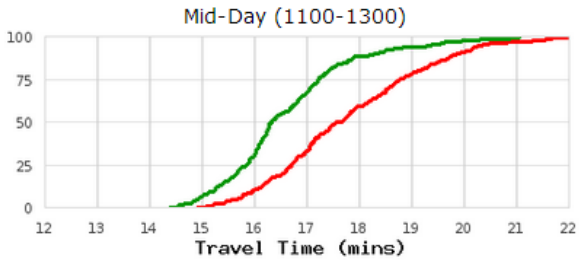

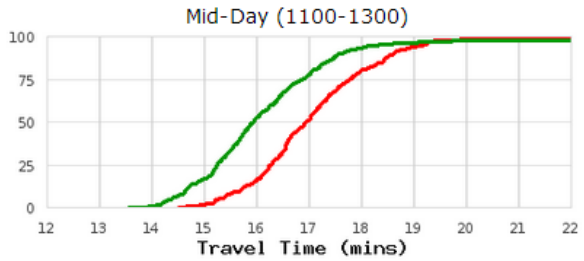

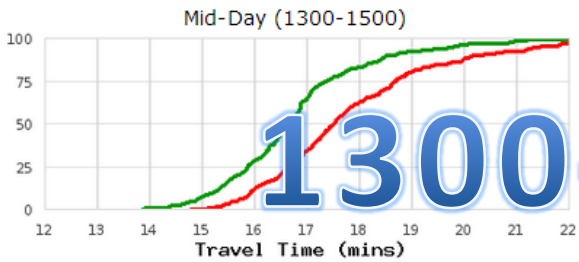

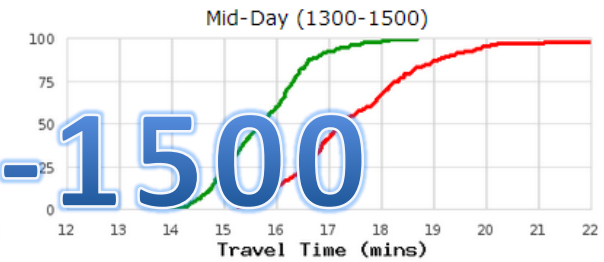

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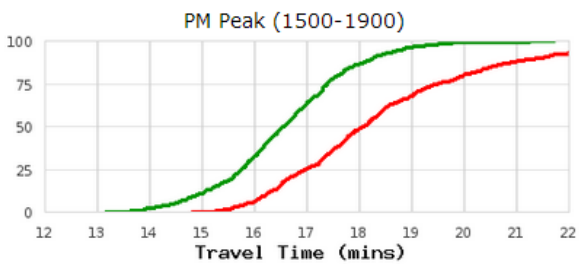

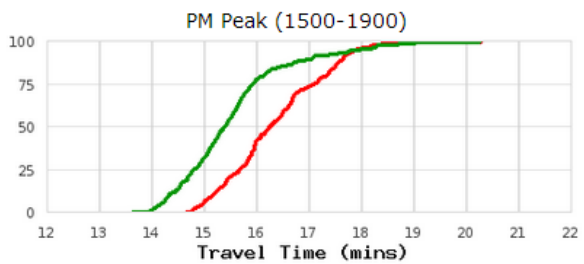

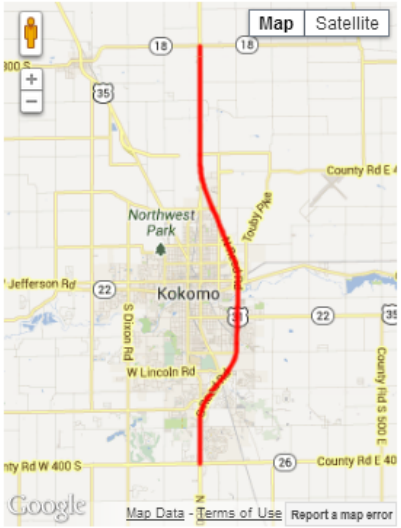

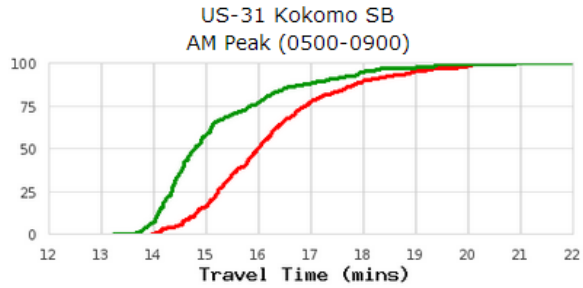

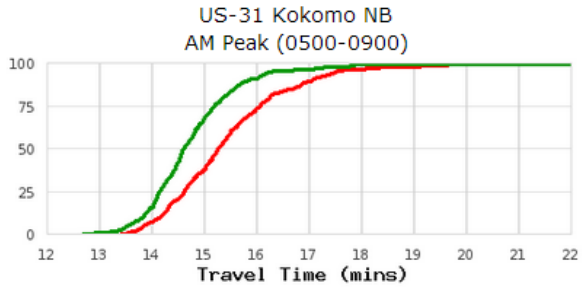

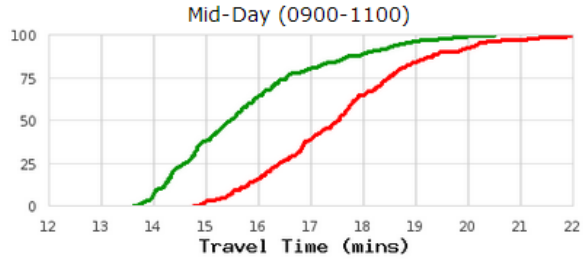

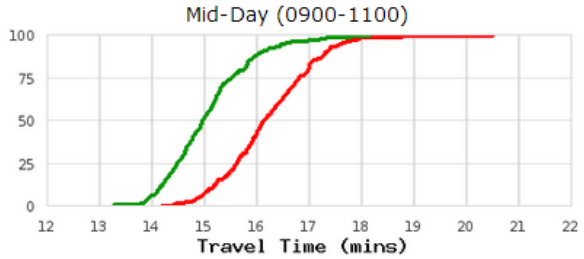

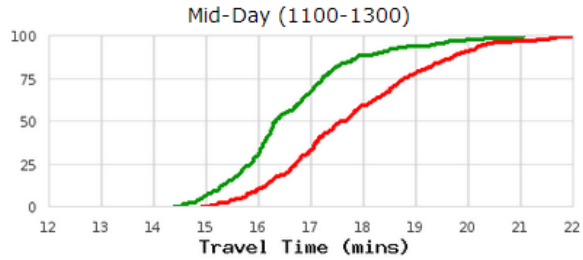

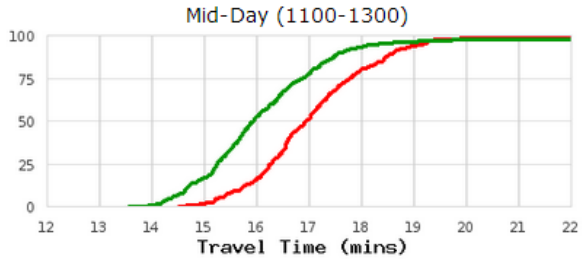

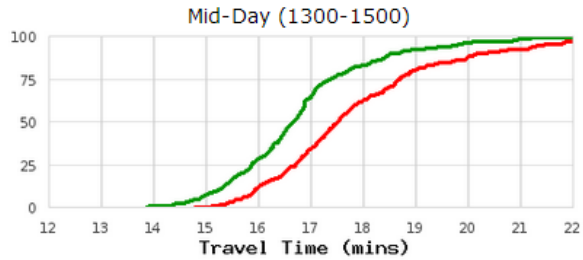

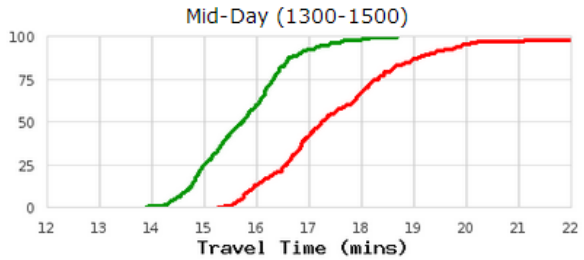

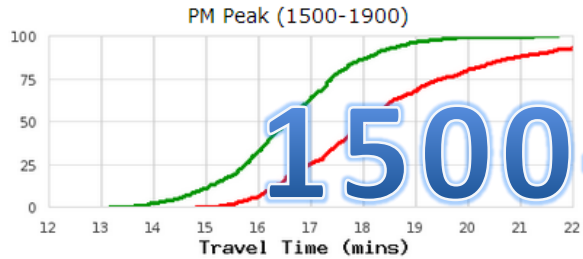

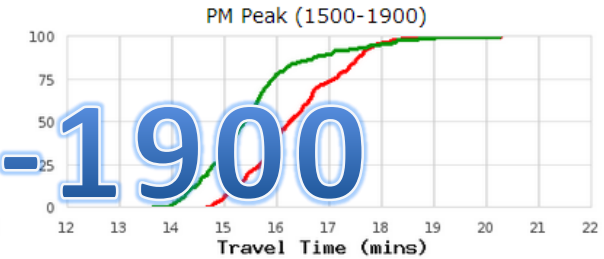

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◄	April 2012					►
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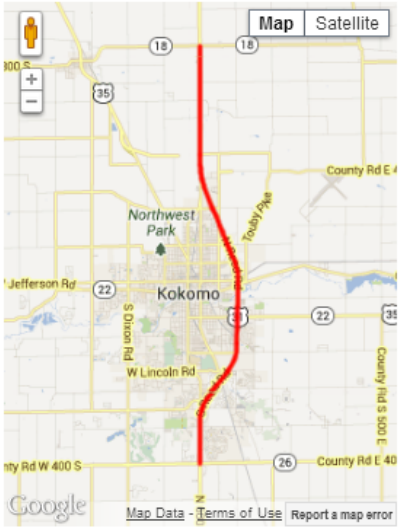

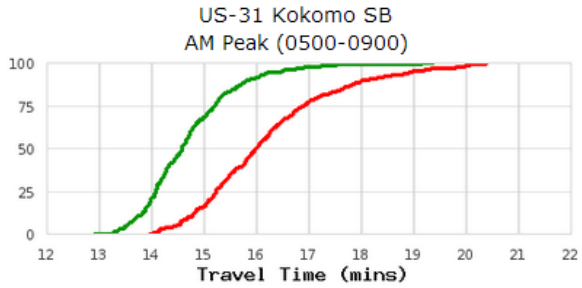

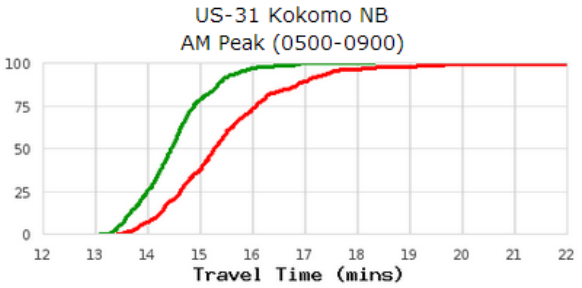

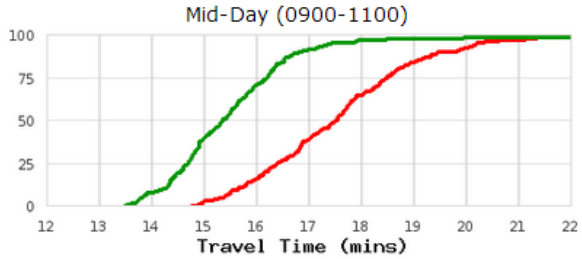

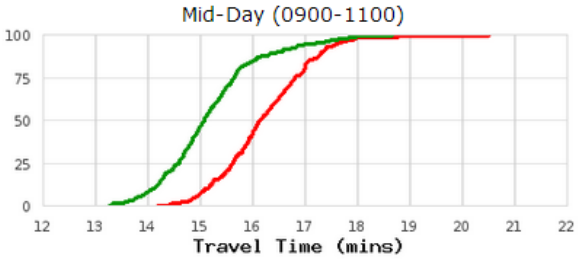

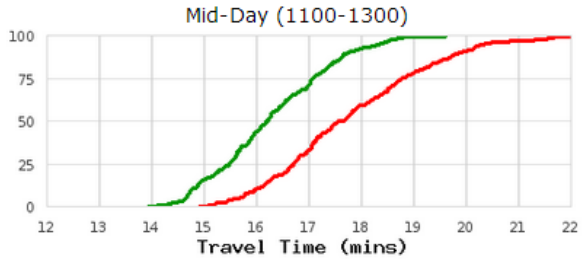

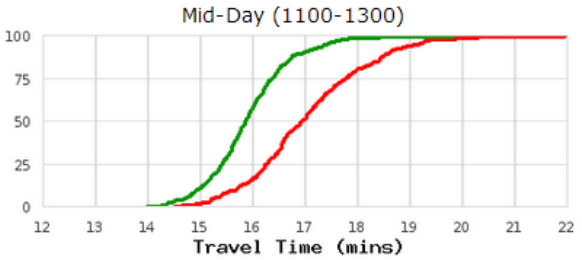

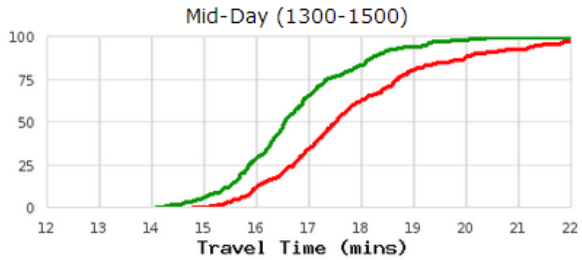

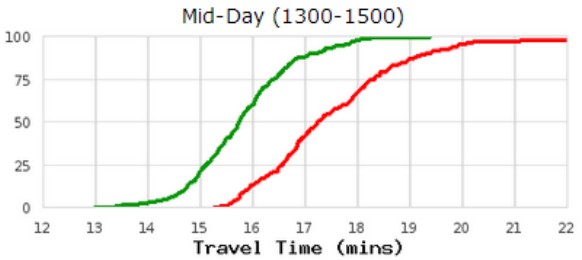

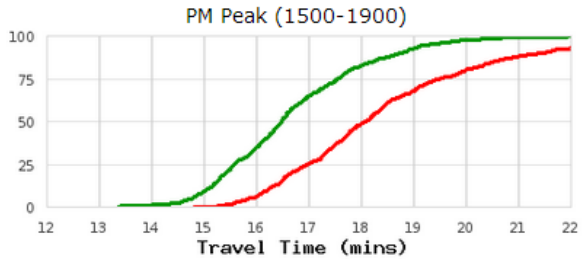

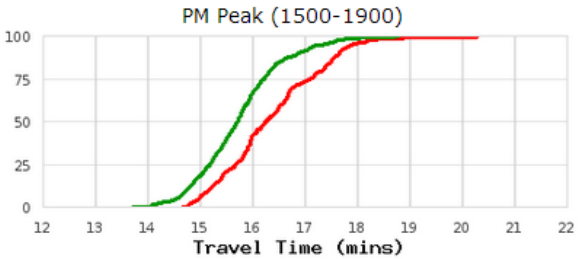

March 2012

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April 2012

Sun	Mon	Tue	Wed	Thu	Fri	Sat
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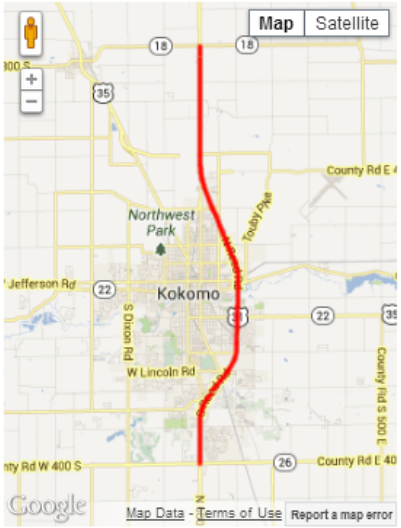
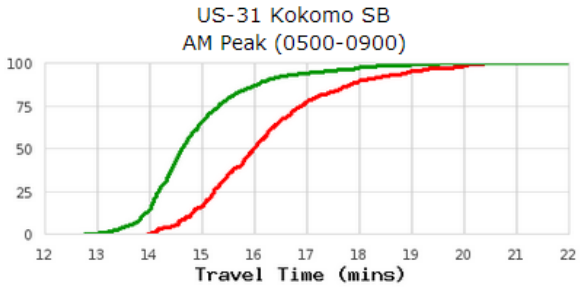
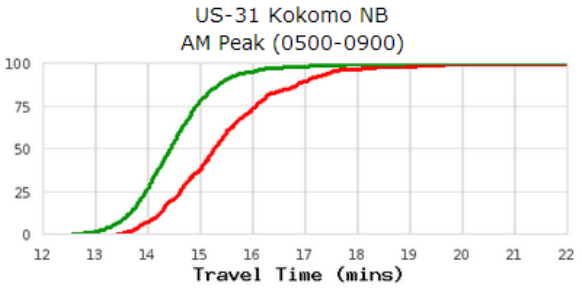
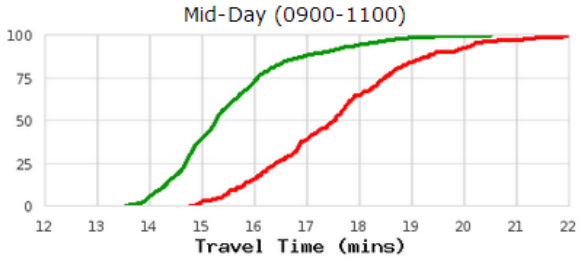
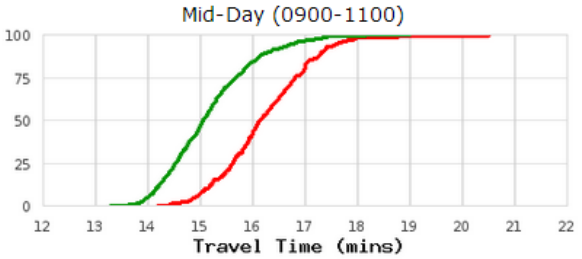
Apr 12

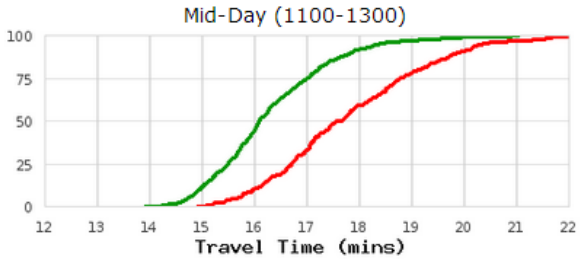


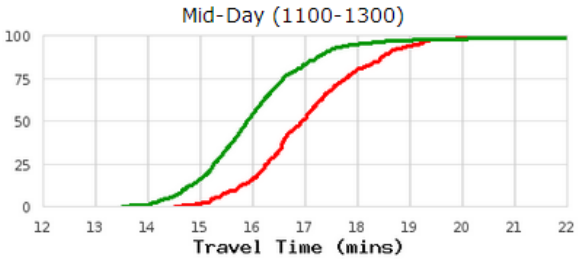


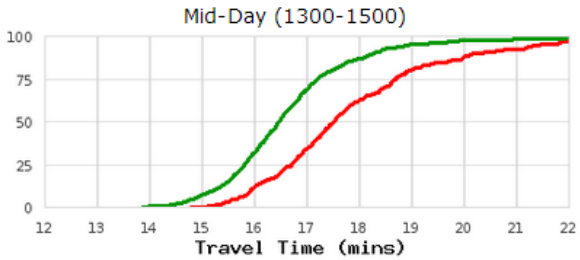


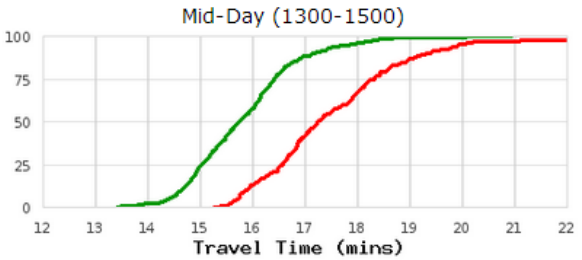


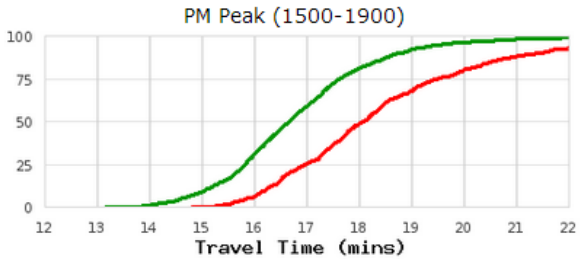


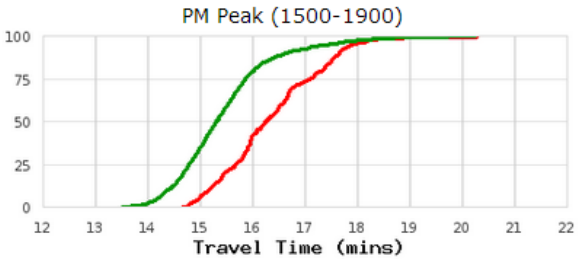












◄	March 2012					►
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◄	May 2012					►
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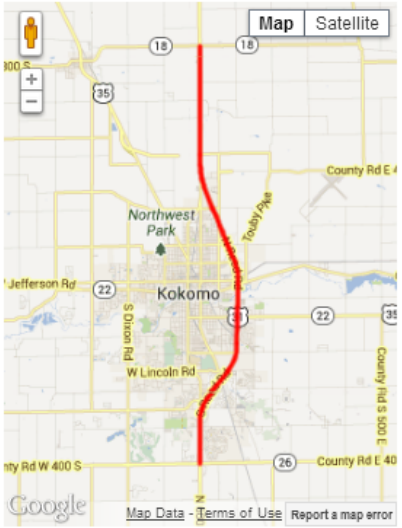
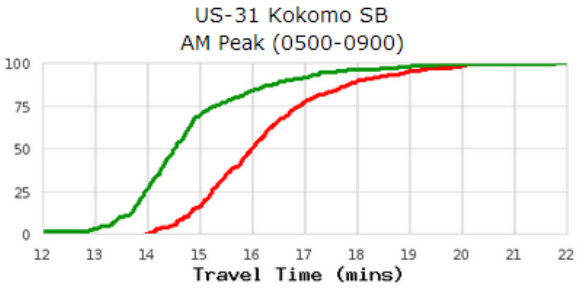
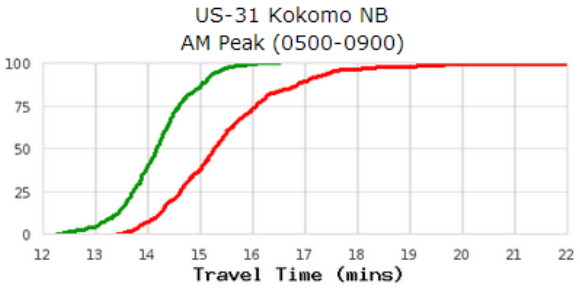
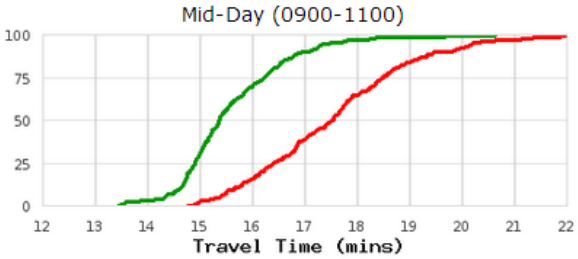
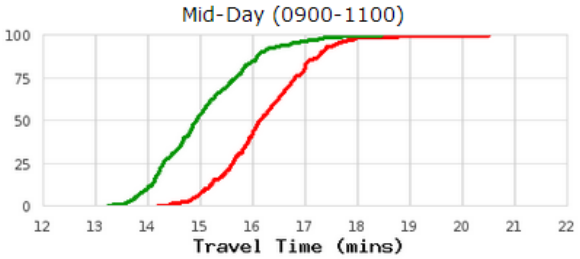
May 12

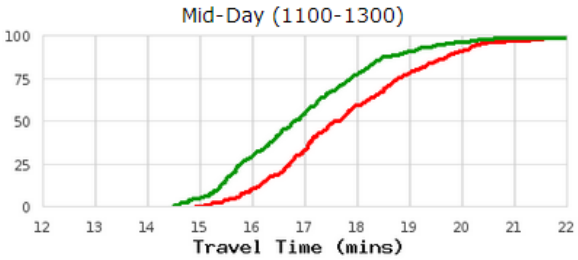


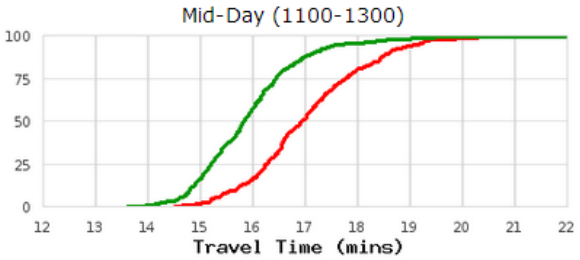


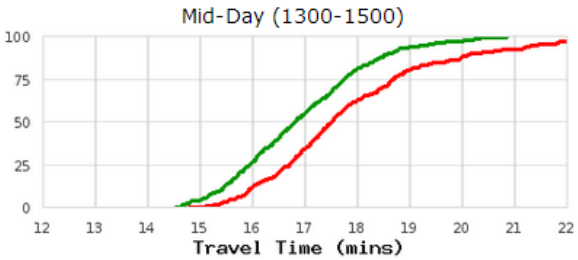


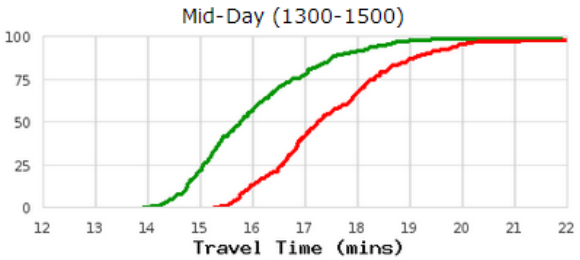


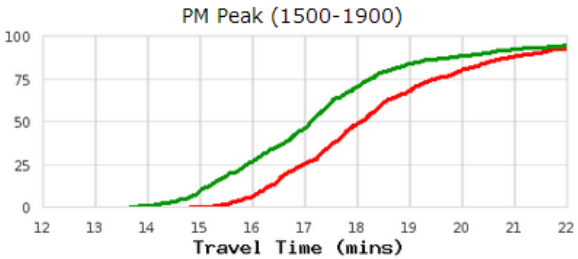


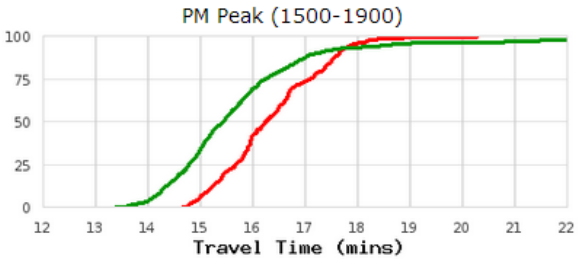












◄	March 2012					►
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◄	June 2012					►
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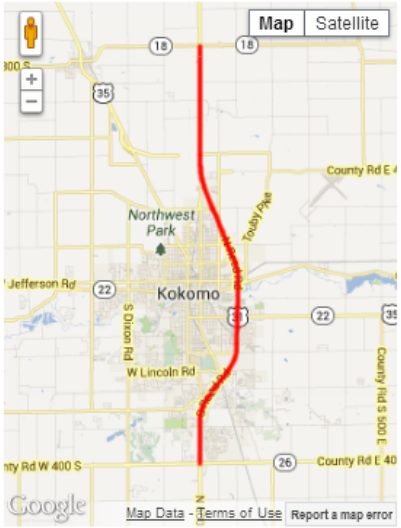
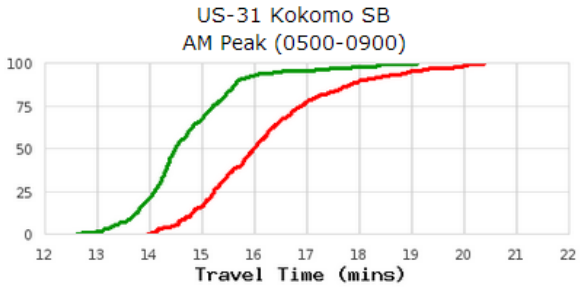
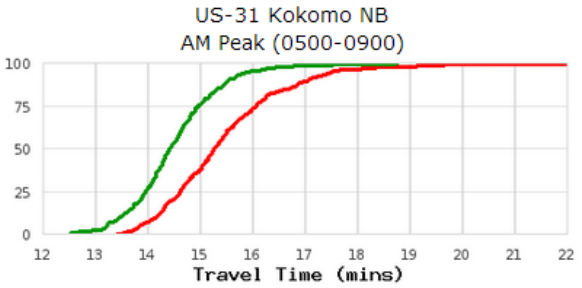
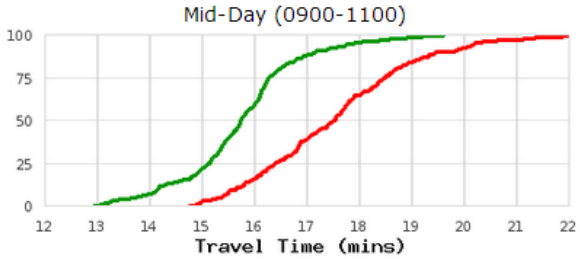
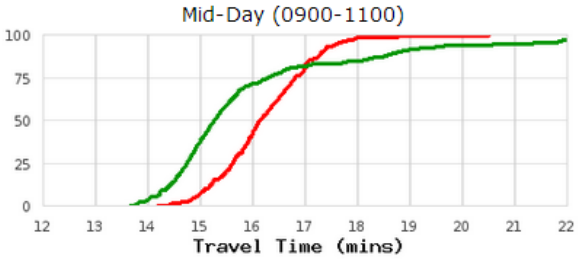
June 12

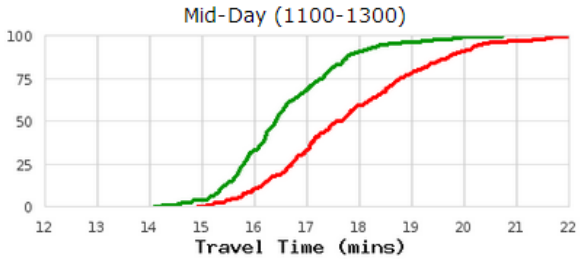


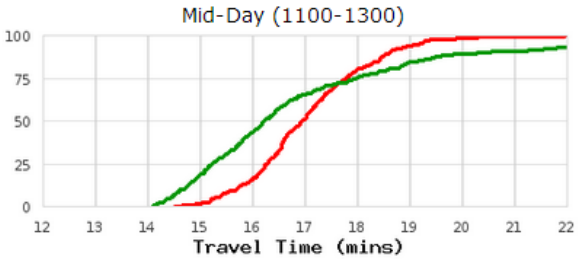


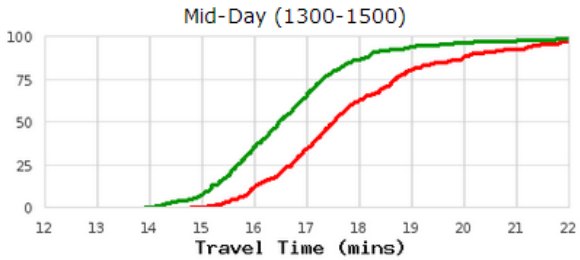


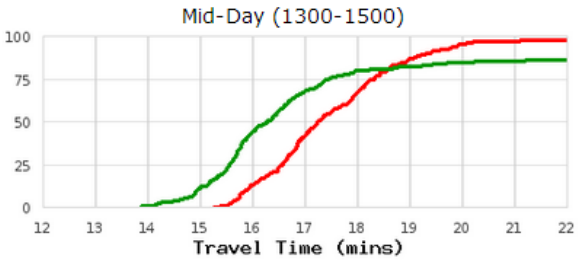


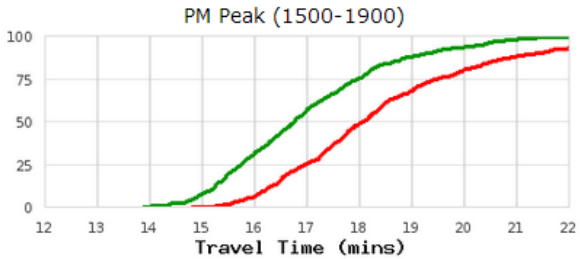


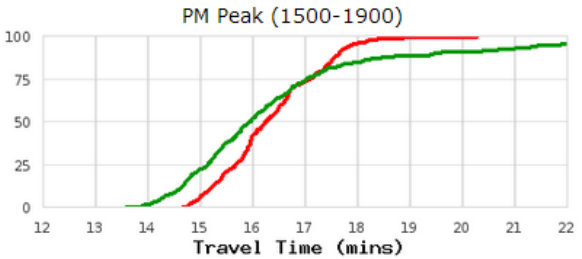












March 2012

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July 2012

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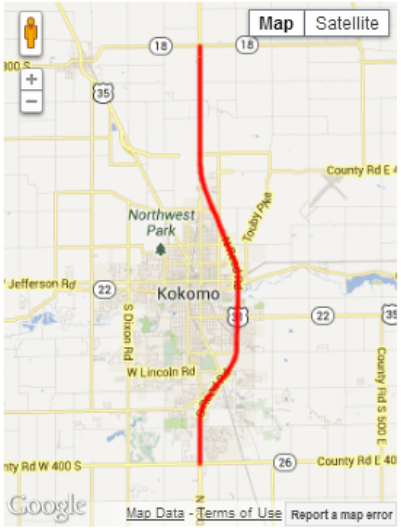
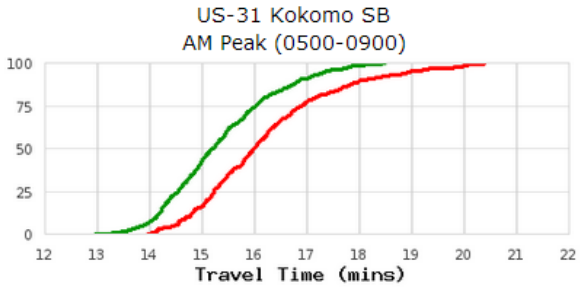
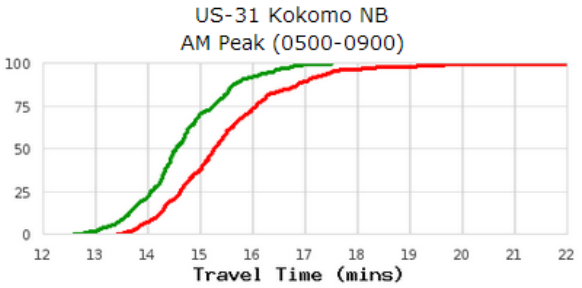
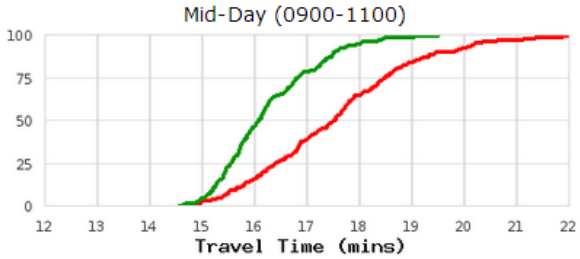
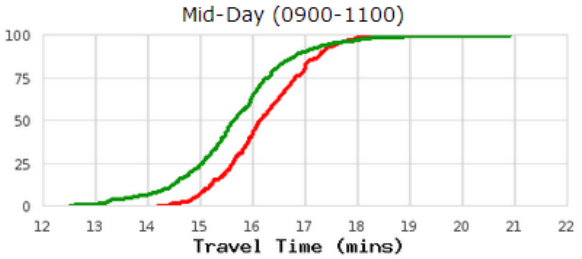
July 12

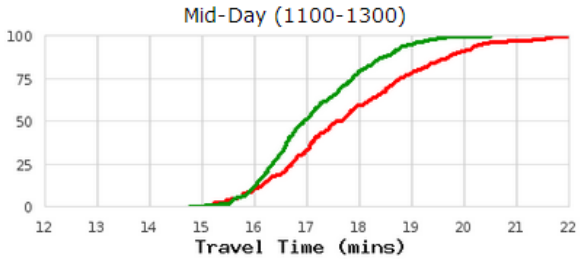


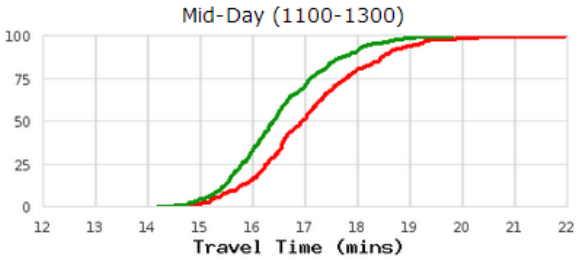


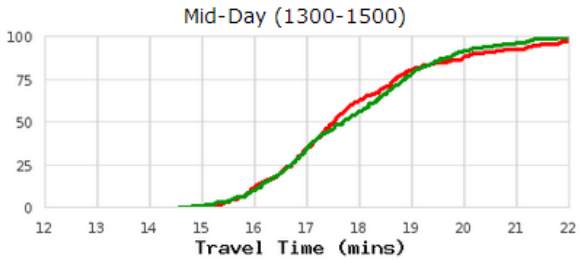


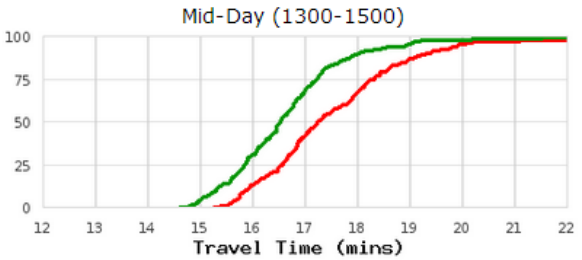


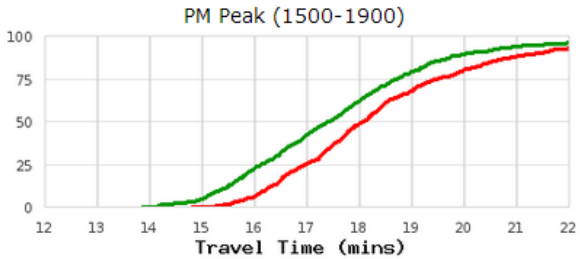


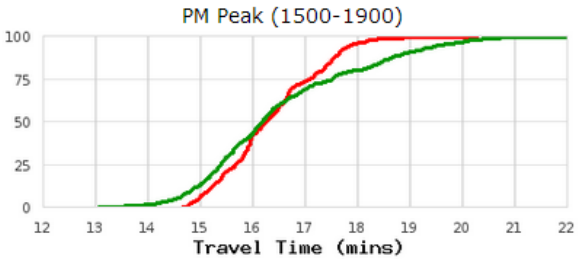












◄	March 2012					►
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18	19	20	21	22	23	24
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1	2	3	4	5	6	7

◄	August 2012					►
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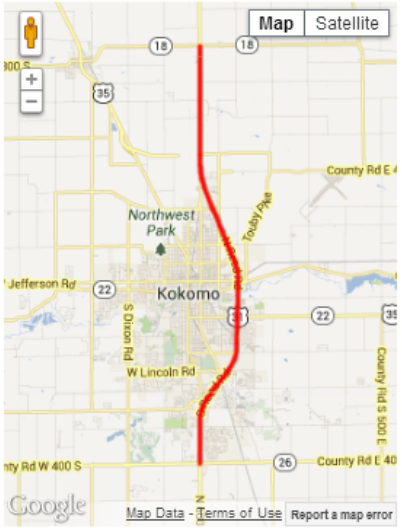
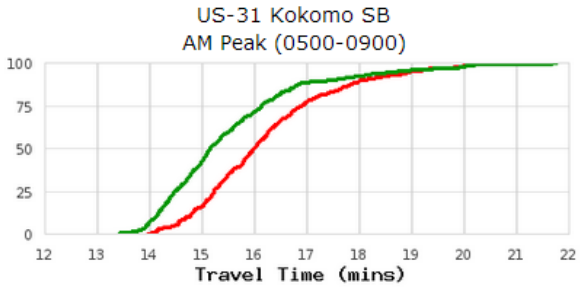
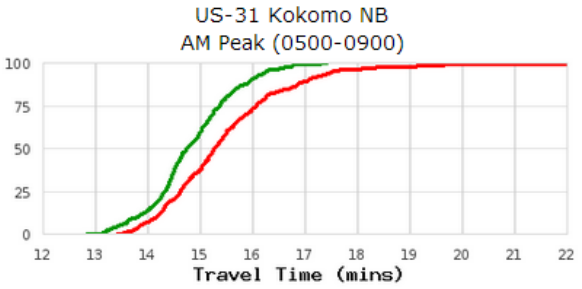
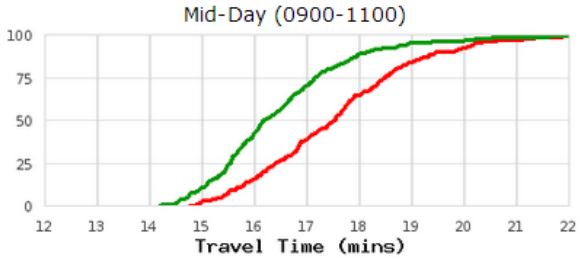
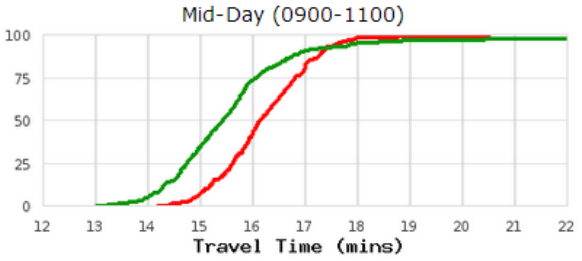
Aug 12

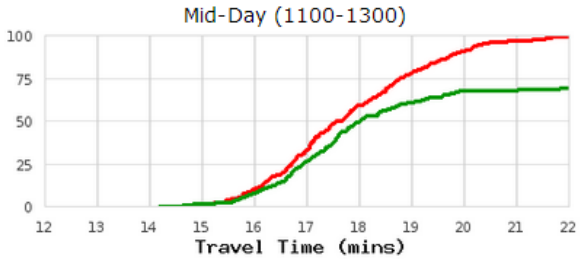


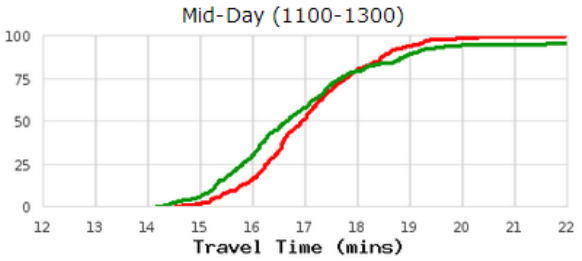


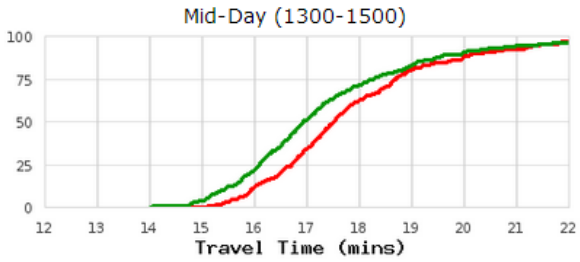


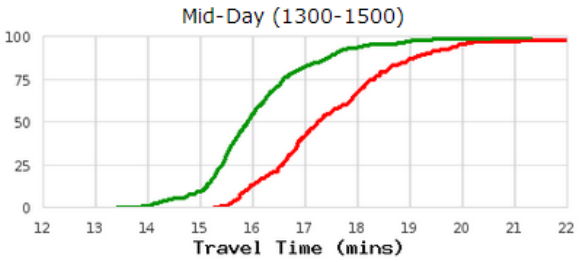


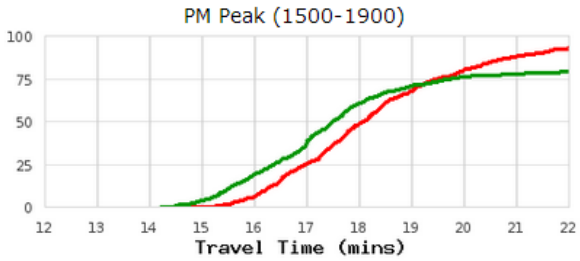


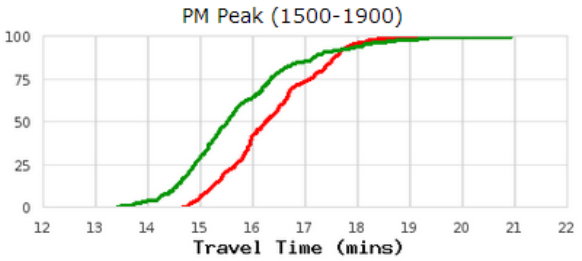












March 2012

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September 2012

Sun	Mon	Tue	Wed	Thu	Fri	Sat
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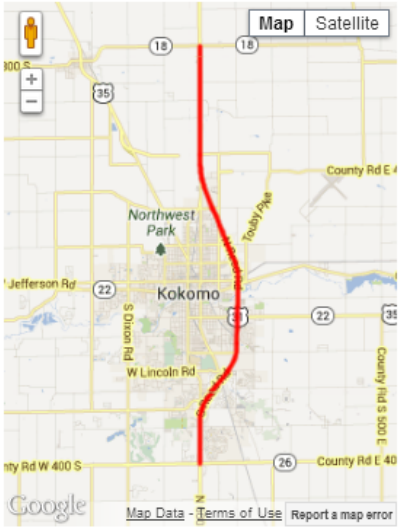
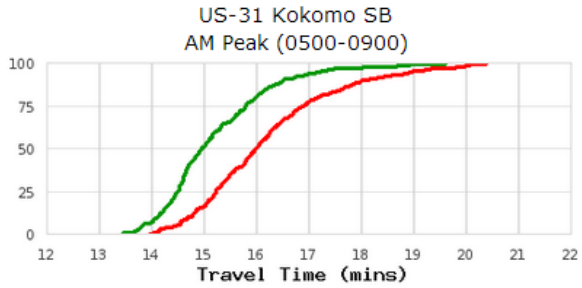
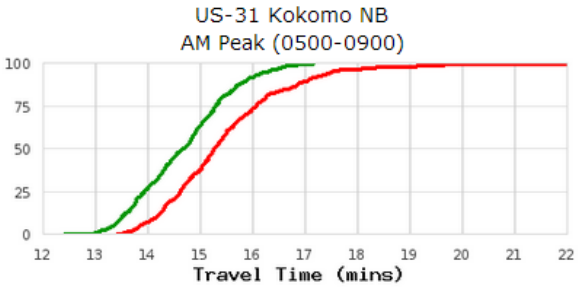
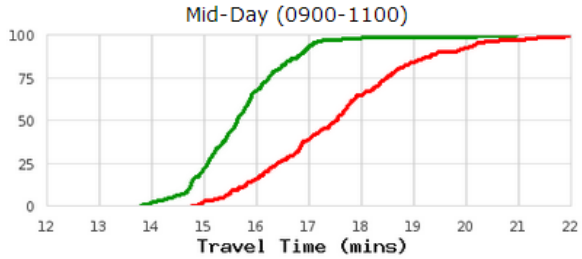
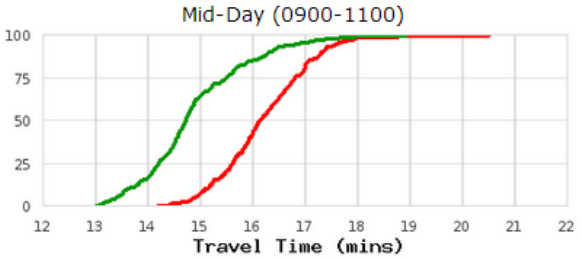
Sept 12

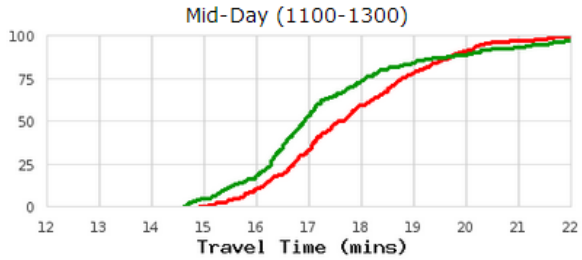


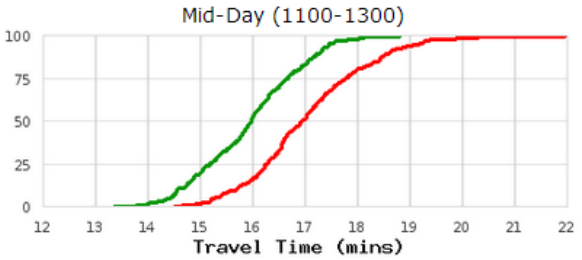


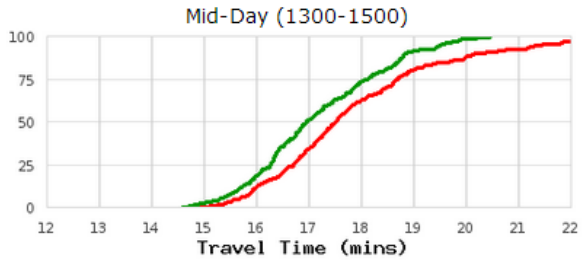


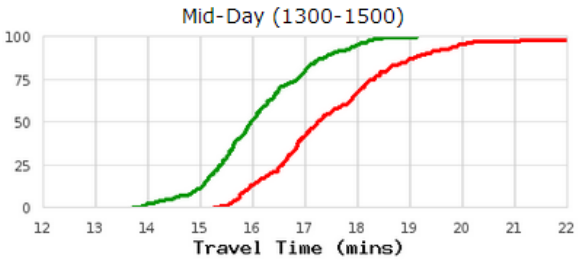


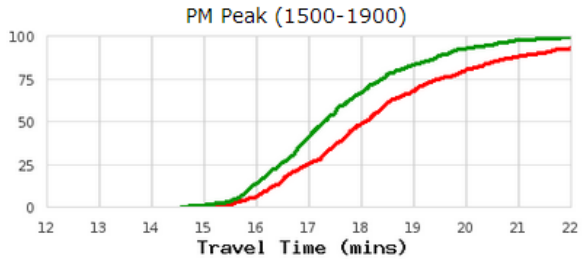


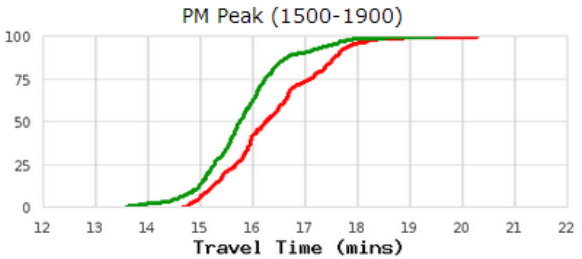












March 2012

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October 2012

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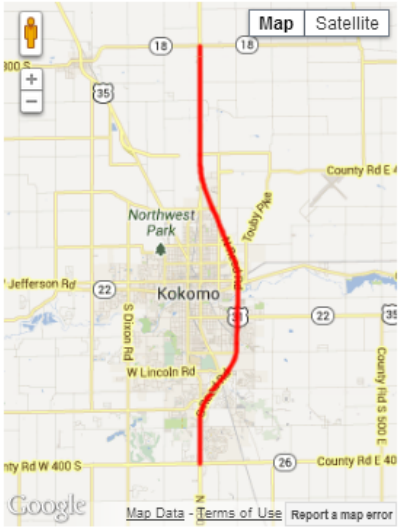
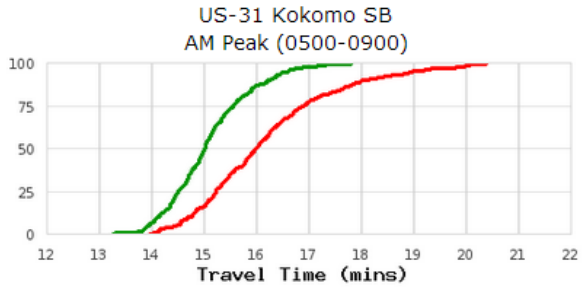
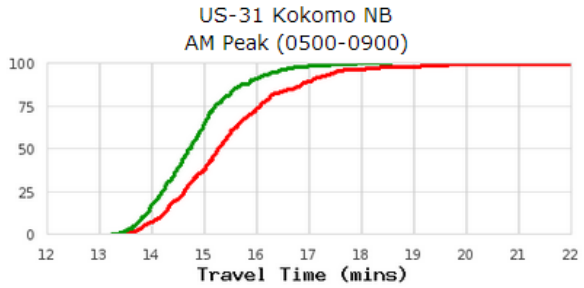
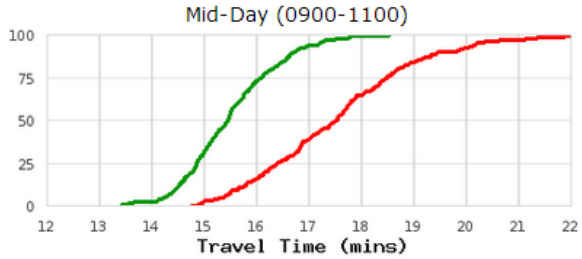
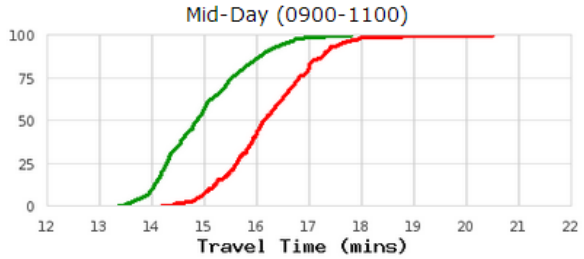
Oct 12

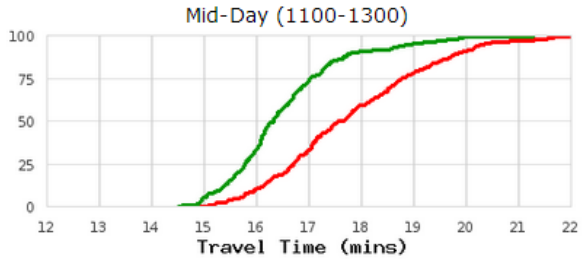


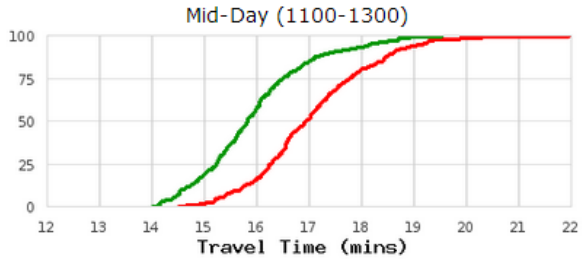


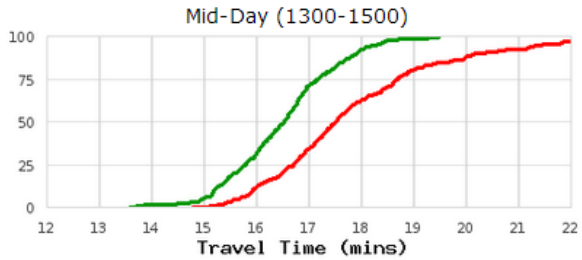


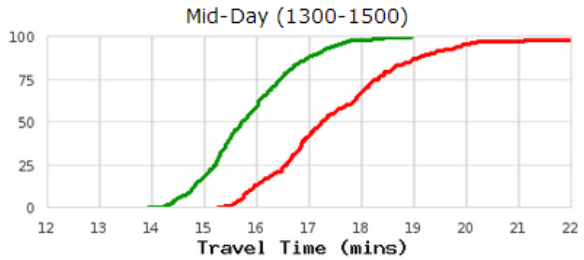


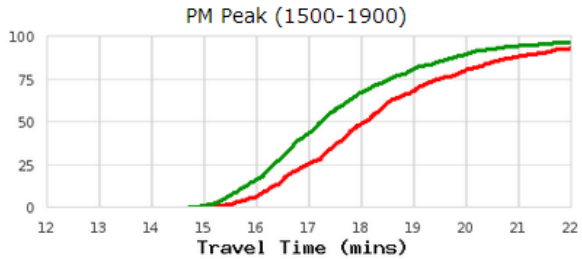


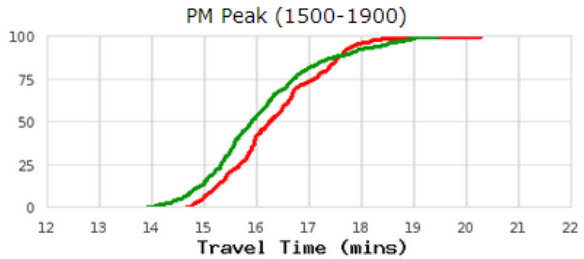












March 2012

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18	19	20	21	22	23	24
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November 2012

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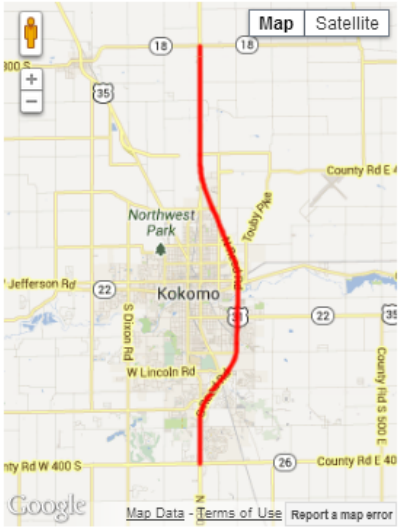
2	3	4	5	6	7	8

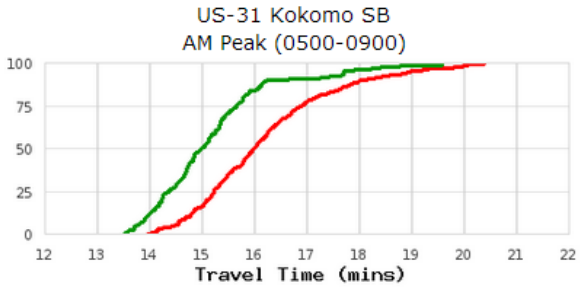
Nov 12

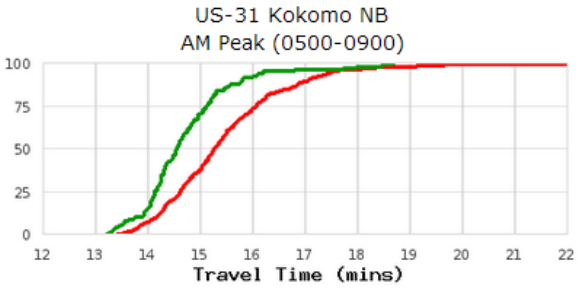


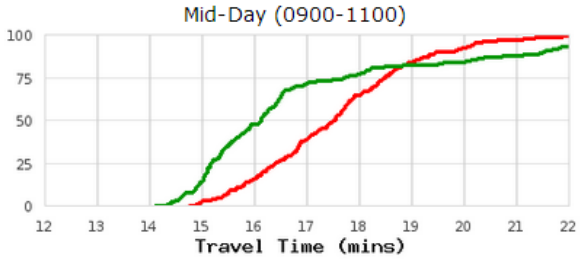
◄	March 2012					►
Sun	Mon	Tue	Wed	Thu	Fri	Sat
26	27	28	29	1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31
1	2	3	4	5	6	7

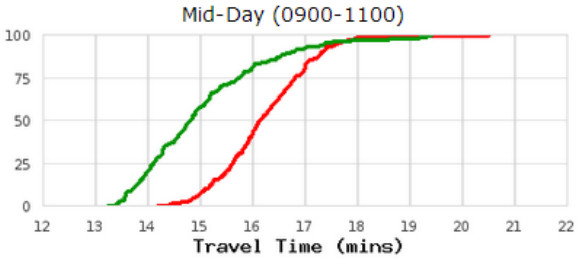
◄	December 2012					►
Sun	Mon	Tue	Wed	Thu	Fri	Sat
25	26	27	28	29	30	1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31	1	2	3	4	5

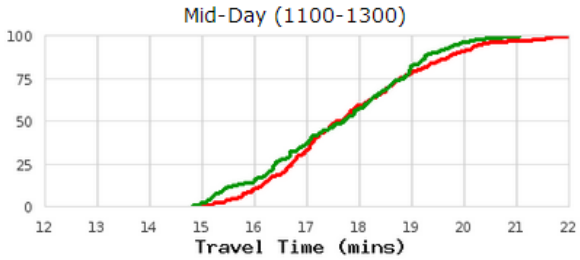
Dec 12

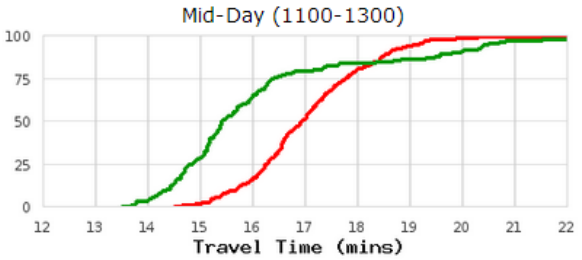


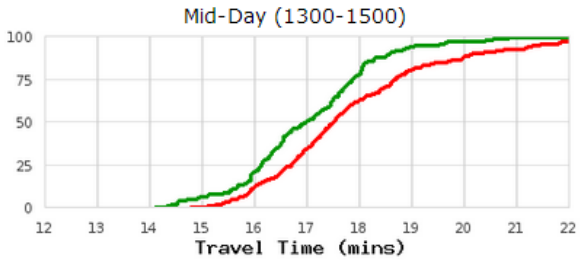


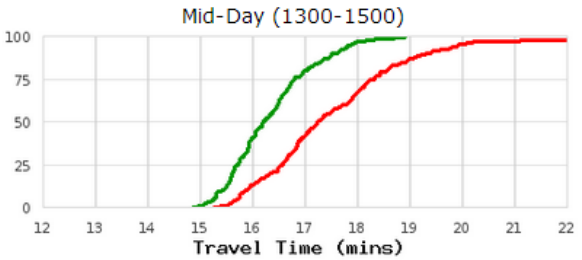


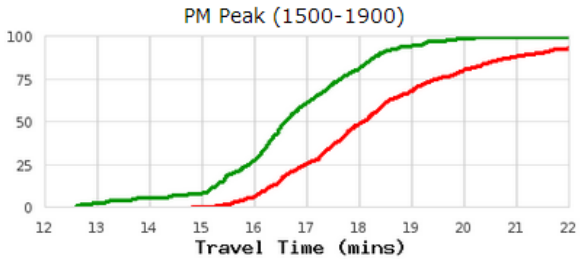


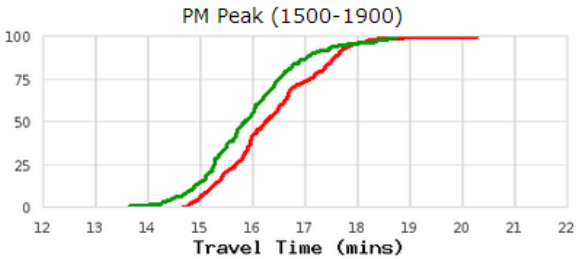


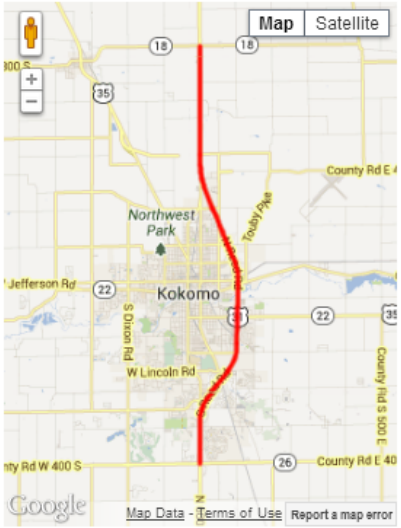


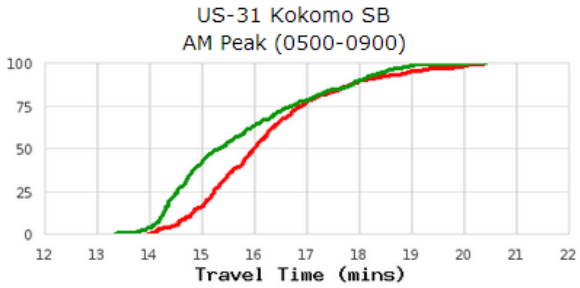


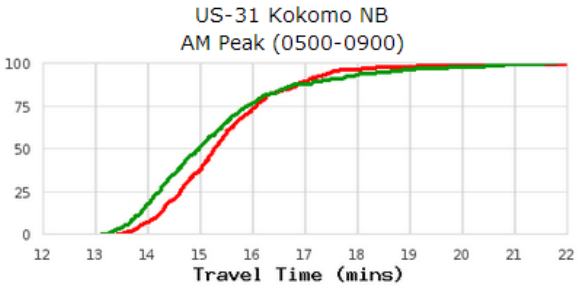


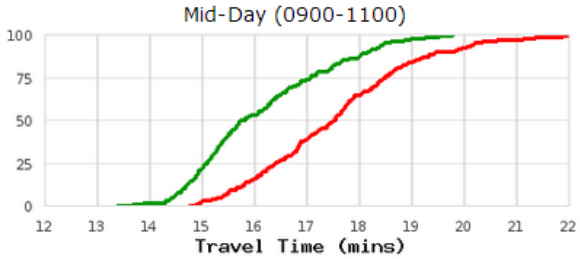


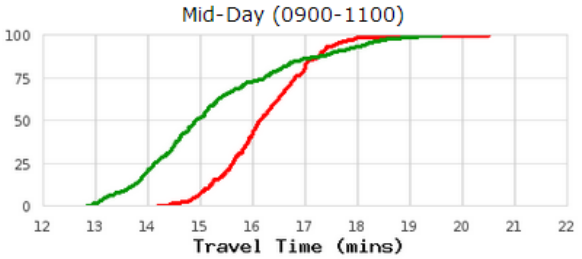


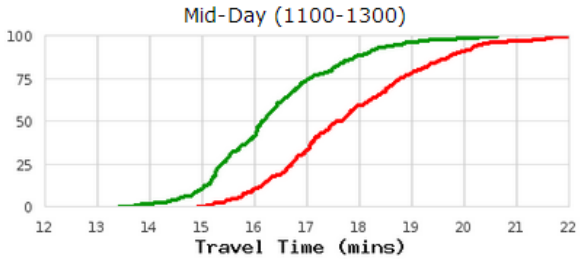


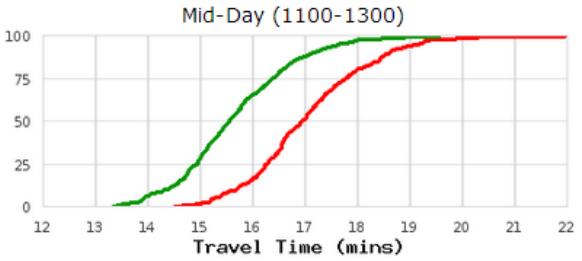


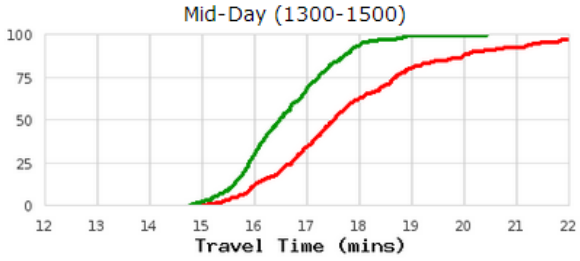


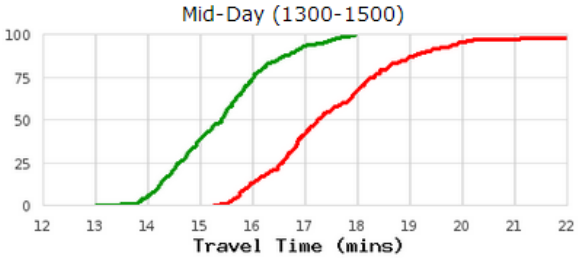


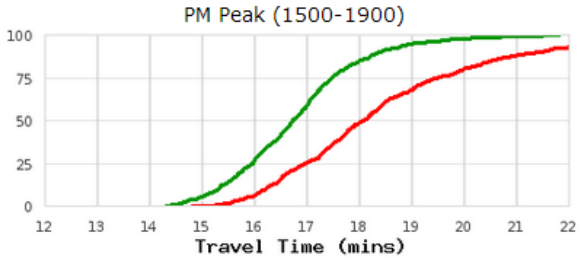


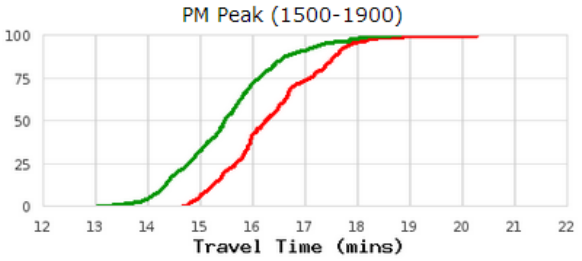








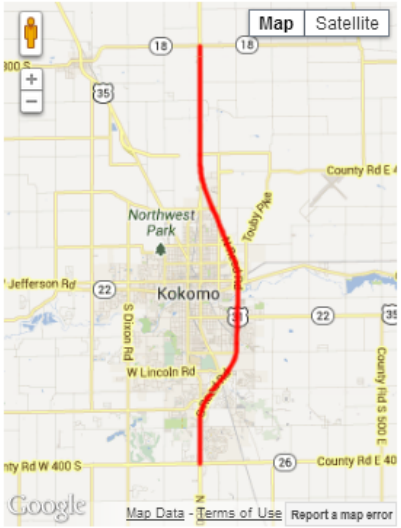


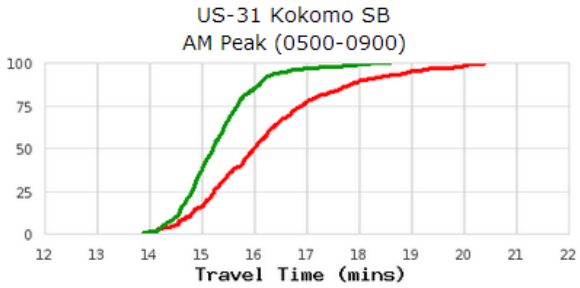


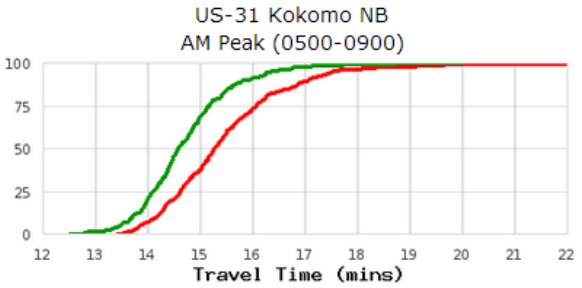
◄	March 2012					►
Sun	Mon	Tue	Wed	Thu	Fri	Sat
26	27	28	29	1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	**26**	**27**	**28**	**29**	**30**	31
1	2	3	4	5	6	7

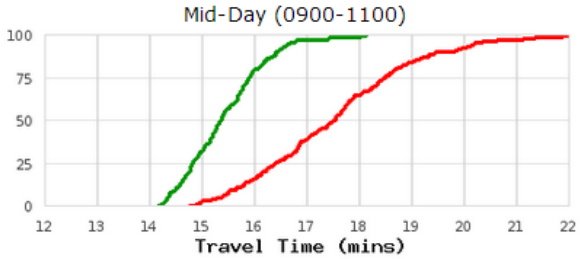
◄	January 2013					►
Sun	Mon	Tue	Wed	Thu	Fri	Sat
30	31	1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	**21**	**22**	**23**	**24**	**25**	26
27	28	29	30	31	1	2
3	4	5	6	7	8	9

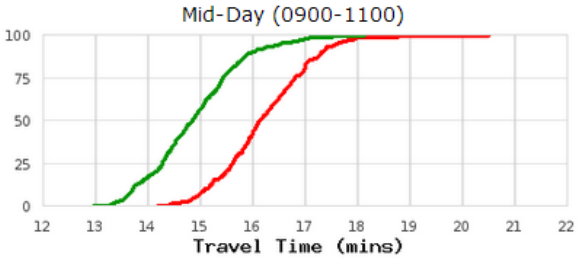
Jan 13

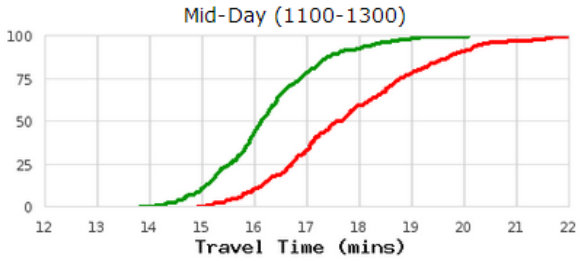


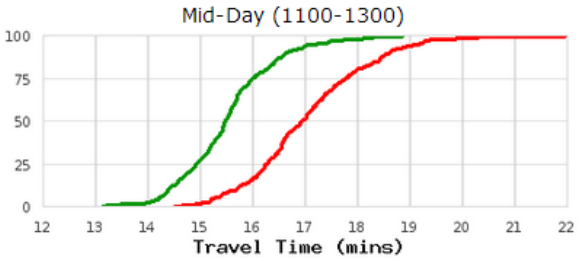


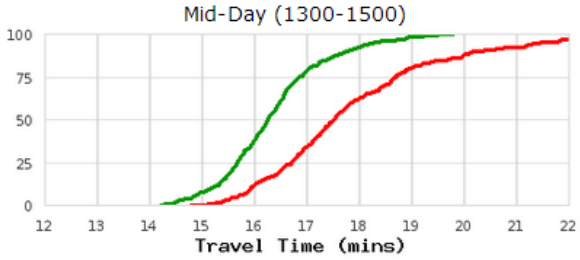


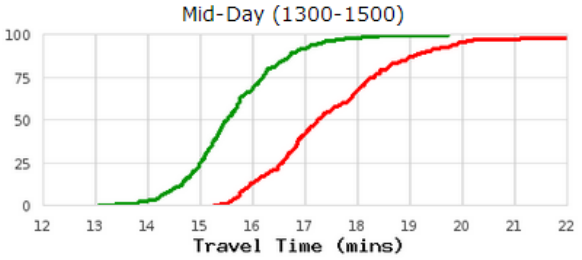


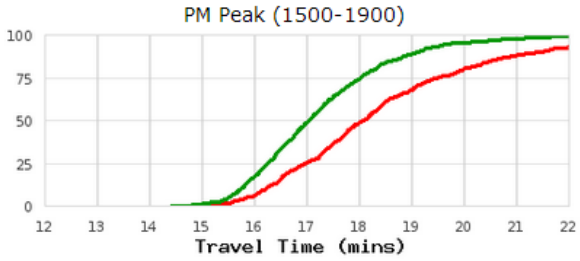


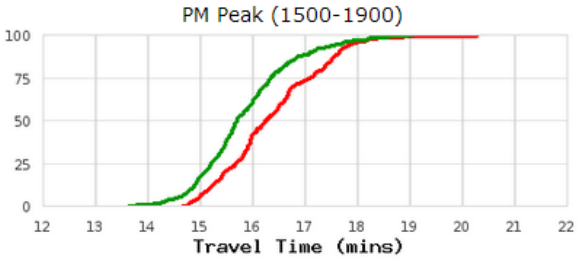












◄	March 2012					►
Sun	Mon	Tue	Wed	Thu	Fri	Sat
26	27	28	29	1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31
1	2	3	4	5	6	7

◄	February 2013					►
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	1	2
3	4	5	6	7	8	9

Feb 13

Construction

Arterial Retiming Cost –Benefit Analysis (**weekly**)

MARCH 2012						
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	31

Before Retiming

Week 13

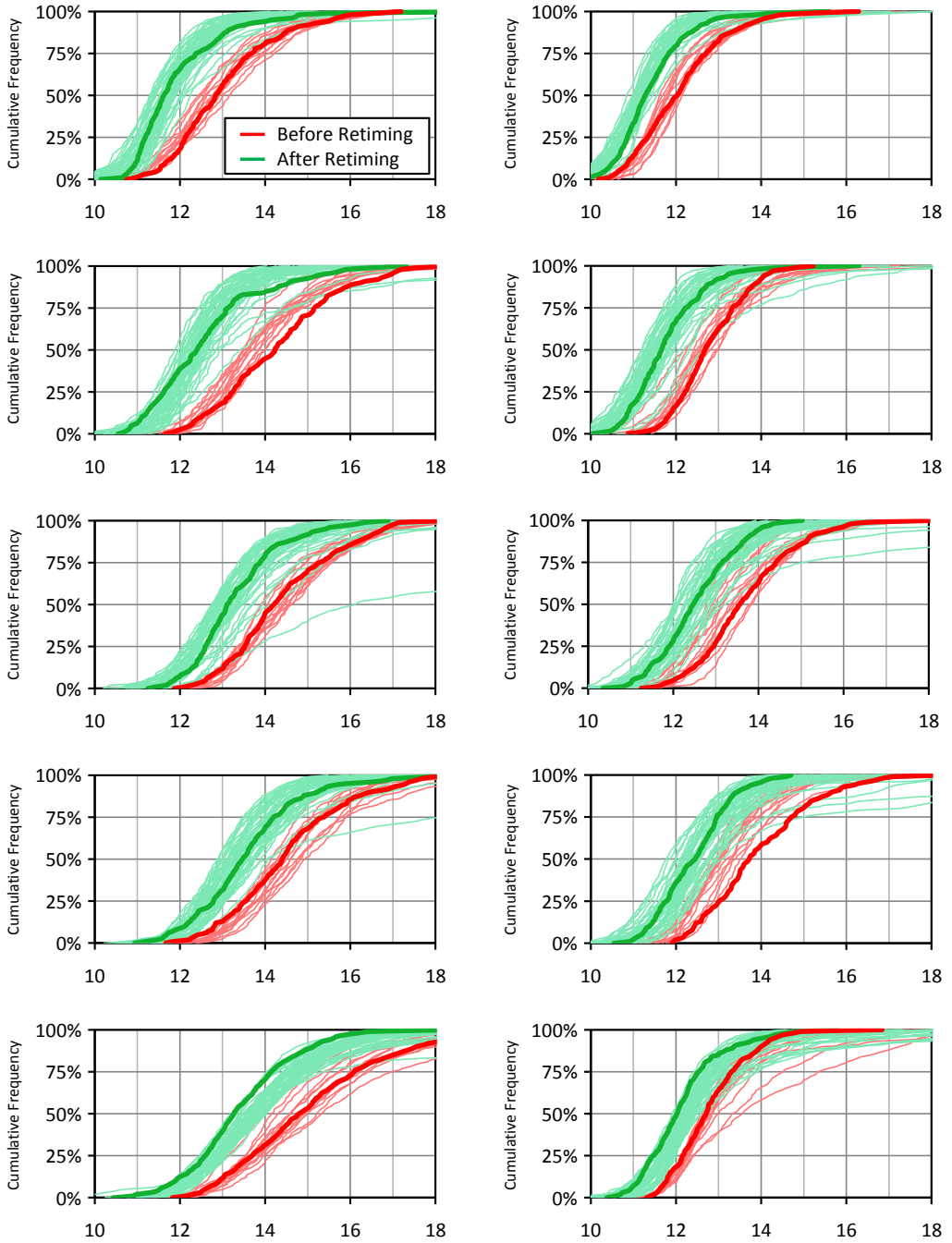
APRIL 2012						
S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

Retiming

Week 15

Week 16

After Retiming



Arterial Retiming Cost –Benefit Analysis (**monthly**)

MARCH 2012

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	31

Before Retiming

Week 13

APRIL 2012

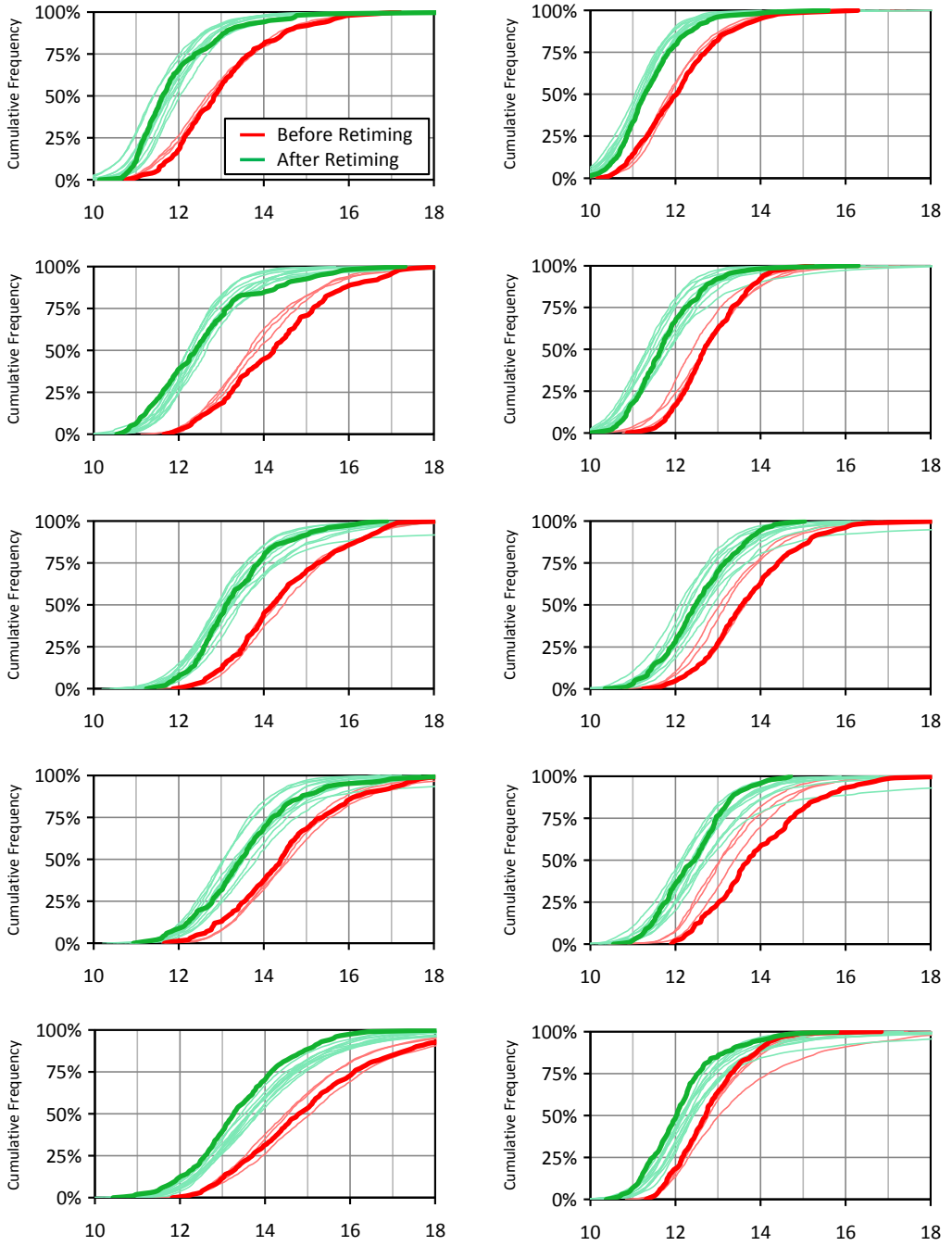
S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

Retiming

Week 15

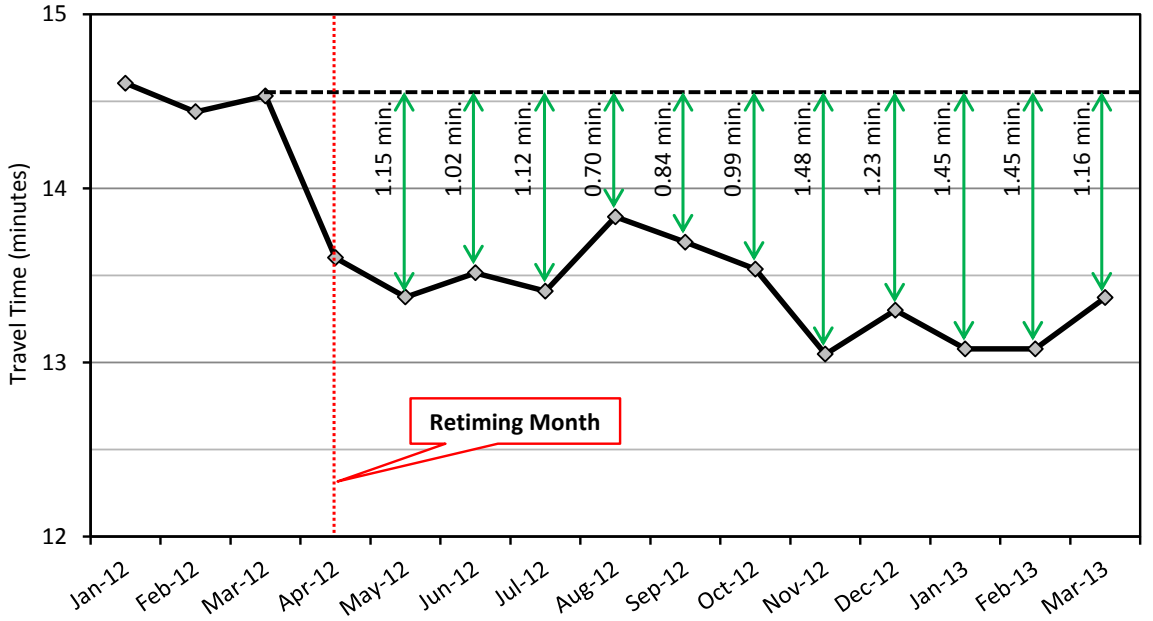
Week 16

After Retiming

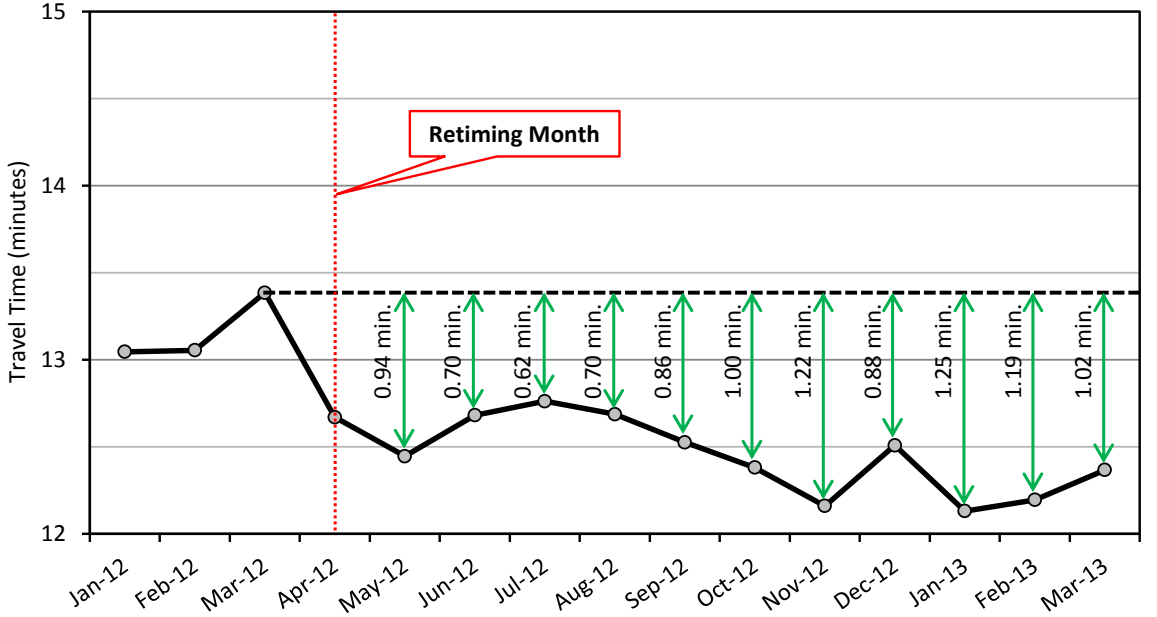


Timing Plan 4 (1300 – 1500) Median Monthly Travel Times

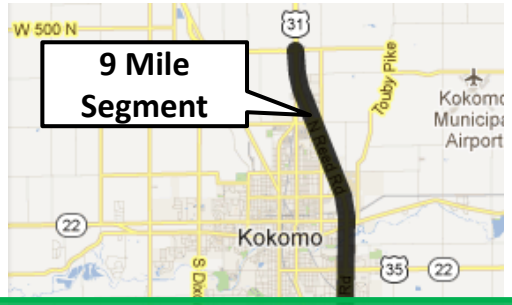
Southbound



Northbound



Arterial Retiming Cost – Benefit Analysis using Crowd Sourced Data



Carbon Savings

Using TTI Travel Time Savings Calculations: Yearly Savings are $2.7 Million

	Plan	Median TT Savings (min)	% of Daily Traffic	TT Savings (h)	TTI Travel Time Savings ($)	CO2 Reduction (tons)	CO2 Emission Savings ($)
Northbound US 31	Plan 0 (0000 – 0500)	0.79	2.2%	1987.34	$ 46,941.69	16.77	$ 368.96
	Plan 1 (0500 – 0900)	1.22	7.2%	9925.88	$ 234,453.24	83.76	$ 1,842.82
	Plan 2 (0900 – 1100)	1.83	5.3%	10877.93	$ 256,941.12	91.80	$ 2,019.58
	Plan 3 (1100 – 1300)	1.1	6.7%	8246.25	$ 194,779.77	69.59	$ 1,530.98
	Plan 4 (1300 – 1500)	0.93	6.6%	6886.14	$ 162,653.47	58.11	$ 1,278.47
	Plan 5 (1500 – 1900)	1.53	13.5%	23311.22	$ 550,620.34	196.72	$ 4,327.91
	Plan 6 (1900 – 2400)	0.91	7.1%	7319.89	$ 172,898.62	61.77	$ 1,359.00
Southbound US 31	Plan 0 (0000 – 0500)	0.58	2.2%	1462.30	$ 34,540.02	12.34	$ 271.49
	Plan 1 (0500 – 0900)	0.75	7.6%	6420.27	$ 151,649.25	54.18	$ 1,191.97
	Plan 2 (0900 – 1100)	1.02	5.5%	6316.57	$ 149,199.92	53.31	$ 1,172.72
	Plan 3 (1100 – 1300)	1.1	7.0%	8627.08	$ 203,775.18	72.80	$ 1,601.69
	Plan 4 (1300 – 1500)	1.2	7.5%	9881.93	$ 233,415.21	83.39	$ 1,834.66
	Plan 5 (1500 – 1900)	0.69	14.2%	11040.76	$ 260,787.26	93.17	$ 2,049.81
	Plan 6 (1900 – 2400)	0.45	7.9%	4018.4	$ 94,906.91	33.91	$ 745.97
	Total		**100.0%**	**116321.6**	**$ 2,747,562**	**981.64**	**$ 21,596.03**

Before Retiming

MARCH 2012

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
Week 13 25	26	27	28	29	30	31

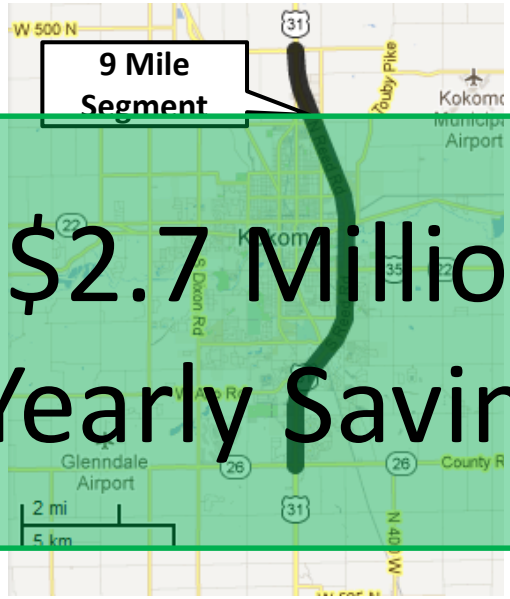
Retiming

APRIL 2012

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

After Retiming

Arterial Retiming Cost – Benefit Analysis using Crowd Sourced Data



$2.7 Million Yearly Savings

MARCH 2012						
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	31

Before Retiming

Week 13

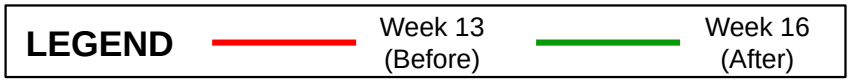
APRIL 2012						
S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

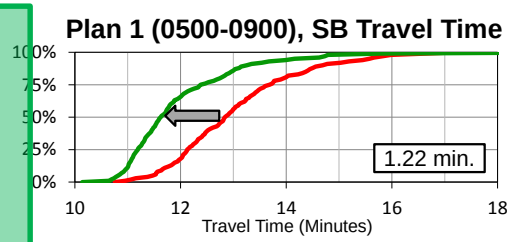
Retiming

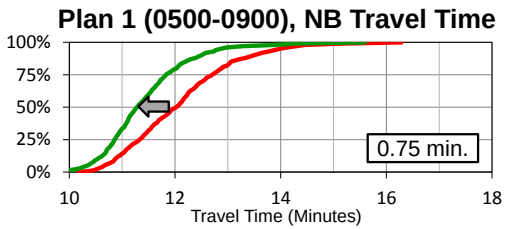
Week 15

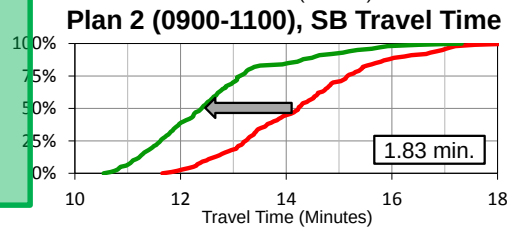
Week 16

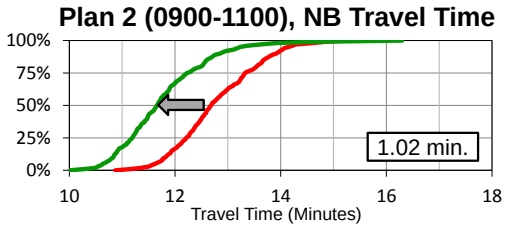
After Retiming

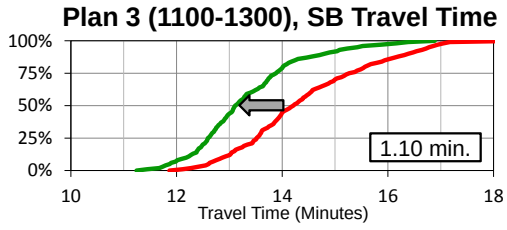


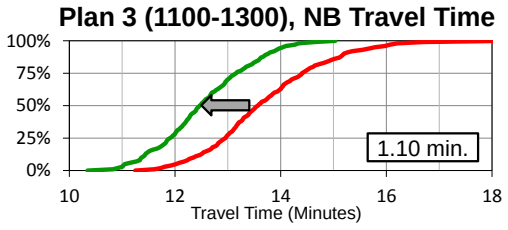


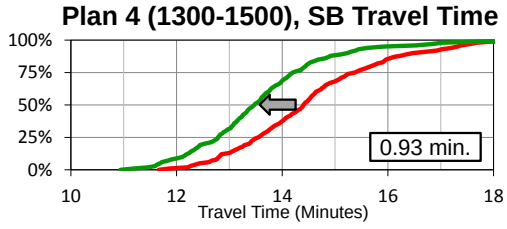


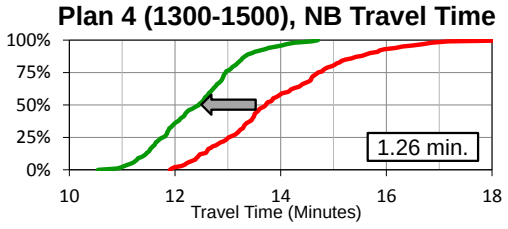


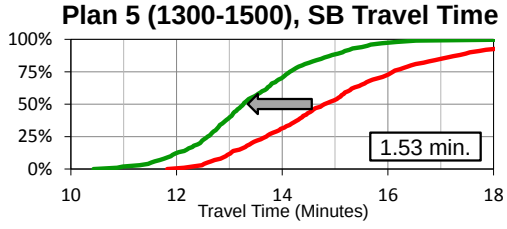


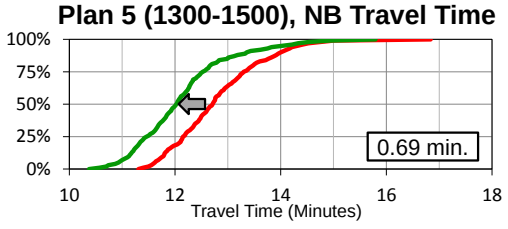












Messages

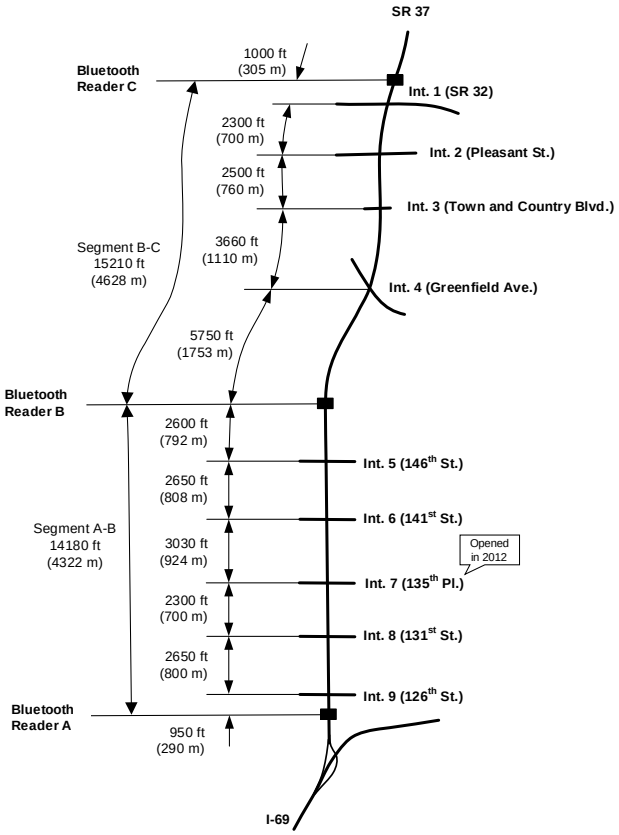
1. Web dissemination
2. Background/Context/Attribution
3. Performance Measure Pyramid
   - Communication
   - Detectors
   - Splits
   - Coordination
4. **Longitudinal System Monitoring**
5. **Outcome Assessment Telling Our Story**
6. Performance Measures will not reduce consulting, but I believe their services will evolve

Circa 2009 Probe Monitoring Stations in Indiana

Long Term Installation with Real-Time SQL Based Travel Time Calc

Short Term Battery Powered Device (Traffax)..Data post processed

Short Term Installation with Real-Time SQL Based Travel Time Calc

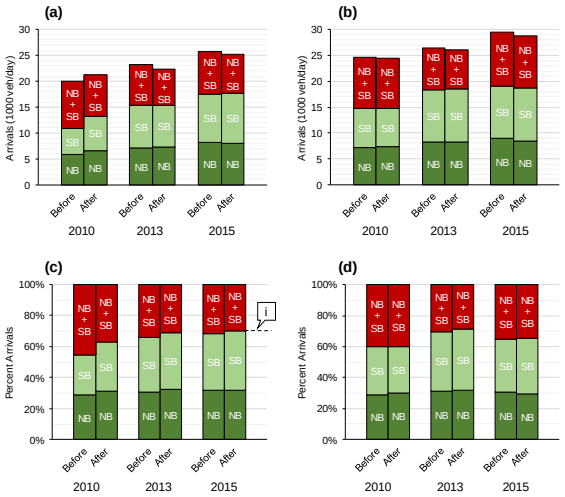


Agencies Need Long-Term Documentation of Coordination Strategies

SR37 North Evaluation: 2010, 2013, 2015

Saturdays

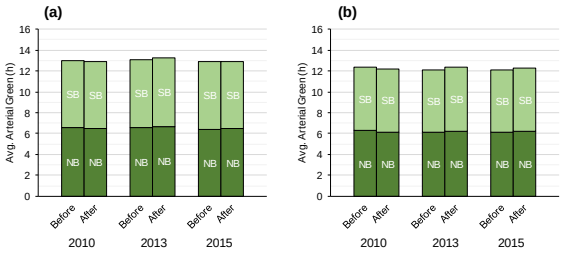
Weekdays



Growth in POG, despite significant increase in volumes

Saturdays

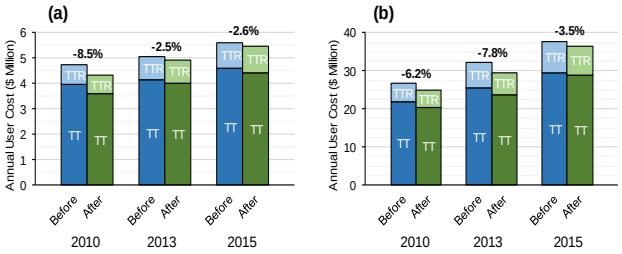
Weekdays



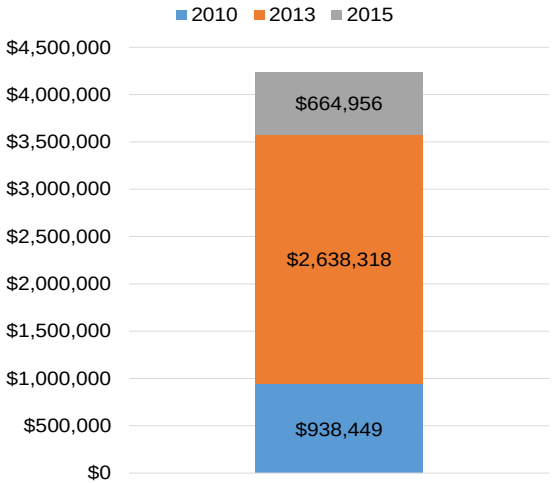
Arterial Green Remained Constant

Saturdays

Weekdays



Significant Travel Time (TT) & Travel Time Reliability (TTR) Cost Reductions After Each Retiming



Total of annualized user benefits from 2010, 2013, and 2015 optimizations: **$4,241,723**

Messages

1. Web dissemination
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6. **Performance Measures will not reduce consulting, but I believe their services will evolve**

Changing the System Management Model

Existing Model:

New Model: