Traffic Signal Performance Measures Workshop

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

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AUTOMATED TRAFFIC SIGNAL PERFORMANCE MEASURES WORKSHOP

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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.

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Browse the contents of Automated Traffic Signal Performance Measures Workshop:

[Presentations and Posters](#)

**Workshop posters &
related manuscripts
available on e-Pubs.**

Posters

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

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

“Volume 1”

Defining Performance Measures...

Download at: tinyurl.com/signalmoee

“Volume 2”

Business Practices, Use Cases, and
Implementation...

Estimated to publish in March 2016

Report Download Page

1. Free

Performance Measures for Traffic Signal Systems: An Outcome-Oriented Approach

Christopher M. Day, *Purdue University*

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Darcy M. Bullock, *Purdue University*

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Howell Li, *Purdue University*

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Steve M. Remias, *Purdue University*

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Alexander M. Hainen, *Purdue University*

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Richard S. Freije, *Purdue University*

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Amanda L. Stevens, *Indiana Department of Transportation*

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James R. Sturdevant, *Indiana Department of Transportation*

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Thomas M. Brennan, *The College of New Jersey*

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Recommended Citation

Day, C. M., D. M. Bullock, H. Li, S. M. Remias, A. M. Hainen, R. S. Freije, A. L. Stevens, J. R. Sturdevant, and T. M. Brennan. *Performance Measures for Traffic Signal Systems: An Outcome-Oriented Approach*. Purdue University, West Lafayette, Indiana, 2014. <http://dx.doi.org/10.5703/1288284315333>

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PERFORMANCE MEASURES FOR TRAFFIC SIGNAL SYSTEMS

An Outcome-Oriented Approach

Christopher M. Day, Darcy M. Bullock, Howell L. Stephen M. Roman, Alexander M. Hansen,
Richard S. Freije, Amanda L. Stevens, James R. Shuckert, and Thomas M. Brennan

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

POOLED FUND STUDY

INDIANAPOLIS

NOVEMBER 12, 2014

PERFORMANCE MEASURES FOR
TRAFFIC SIGNAL SYSTEMS

An Outcome-Oriented Approach

Christopher M. Clay, Cheng M. Dubok, Howard L. Stephens M. Thomas, Alexander M. Thomas,
Howard S. Fraga, Amanda L. Simpson, James H. Shadsworth, and Thomas W. Brennan

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*

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

Probe Data is integral for Outcome Assessment

Advanced
Control

Coordination

Efficient Coordination

OPERATIONS

Timing

Efficient Local Control

Detection

Detector Health

MAINTENANCE

Communications

Working Communications

Advanced
Control

Efficient Coordination

Coordination

OPERATIONS

Efficient Local Control

Timing

Detector Health

Communication

MAINTENANCE

Working Communications

Detection

Jim's Slide

Critical Performance Measures for Managing Signals

Hi Resolution Data is
Critical for Identifying
Levers

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

PERFORMANCE MEASURES FOR TRAFFIC SIGNAL SYSTEMS

An Outcome-Oriented Approach

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

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

PERFORMANCE MEASURES FOR TRAFFIC SIGNAL SYSTEMS

An Outcome-Oriented Approach

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

This workshop is about sharing best practices and developing shared vision

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State of Signal Performance Measures Research

Typical Corridor (22 Intersections)

Traffic Signal Timing Process

Changing the System Management Model

Existing Model:

New Model:

HiRes/Probe Data is a Game Changer and critical for message to decision makers

Messages

1. Web dissemination
2. Background/Context/Attribution
3. Performance Measure Pyramid
 - **Communication**
 - Detectors
 - Splits
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6. Performance Measures will not reduce consulting, but I believe their services will evolve

Communication “Ticker”

SR 49 SR 53 SR 55
US 12 US 30 US 41

----- Total Hi-Res Signals

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**

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

Trailer Camera

Trailer Camera

Initial Data Collection and Analysis

Before/After Comparison

Phase 7 Extension Timer

Extension Timer = 3.0 seconds

ROR₅ vs. GOR for an Undersaturated Split (Phase 7)

Start of Green (9:30:24.1)

ROR₅ vs. GOR for an Undersaturated Split (Phase 7)

9:30:25.1

ROR₅ vs. GOR for an Undersaturated Split (Phase 7)

9:30:26.1

ROR₅ vs. GOR for an Undersaturated Split (Phase 7)

9:30:27.1

ROR₅ vs. GOR for an Undersaturated Split (Phase 7)

9:30:28.1

ROR₅ vs. GOR for an Undersaturated Split (Phase 7)

9:30:29.1

ROR₅ vs. GOR for an Undersaturated Split (Phase 7)

9:30:30.1

ROR₅ vs. GOR for an Undersaturated Split (Phase 7)

9:30:31.1

ROR₅ vs. GOR for an Undersaturated Split (Phase 7)

9:30:32.1

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Undersaturated Split (Phase 7)

Start of Yellow (9:30:33.1)

ROR₅ vs. GOR for an Undersaturated Split (Phase 7)

9:30:34.1

ROR₅ vs. GOR for an Undersaturated Split (Phase 7)

9:30:35.1

ROR₅ vs. GOR for an Undersaturated Split (Phase 7)

Start of Red (9:30:36.6)

ROR₅ vs. GOR for an Undersaturated Split (Phase 7)

9:30:37.6

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Undersaturated Split (Phase 7)

9:30:38.6

ROR₅ vs. GOR for an Undersaturated Split (Phase 7)

9:30:39.6

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Undersaturated Split (Phase 7)

9:30:40.6

ROR₅ vs. GOR for an Undersaturated Split (Phase 7)

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

ROR₅ vs. GOR for an Undersaturated Split (Phase 7)

ROR₅ vs. GOR for an Undersaturated Split (Phase 7)

ROR₅ vs. GOR Plot for an Undersaturated Left Turn

Phase 4 Extension Timer

Extension Timer = 3.0 seconds

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

12:52:22.1

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

12:52:23.1

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

12:52:24.1

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

12:52:25.1

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

12:52:26.1

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

12:52:27.1

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

12:52:28.1

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

12:52:29.1

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

12:52:30.1

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

12:52:31.1

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

12:52:32.1

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

12:52:33.1

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

12:52:34.1

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

12:52:35.1

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

12:52:36.1

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

12:52:37.1

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

12:52:38.1

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

12:52:39.1

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

Start of Yellow (12:52:40.1)

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

12:52:41.1

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

12:52:42.1

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

12:52:43.1

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

Start of Red (12:52:44.1)

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

12:52:45.1

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

12:52:46.1

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

12:52:47.1

Calculation Illustration of GOR and ROR₅

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

12:52:48.1

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

5 Seconds After Start of Red (12:52:49.1)

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

ROR₅ vs. GOR for an Oversaturated Split (Phase 4)

ROR₅ vs. GOR Plot for an Oversaturated Thru Movement

ROR₅ vs. GOR and/or V/C Ratio Summary (0900-1500)

Phase 1 ROR₅ vs. GOR

Phase 2 ROR₅ vs. GOR

Phase 3 ROR₅ vs. GOR

Phase 4 ROR₅ vs. GOR

Phase 5 ROR₅ vs. GOR

Phase 6 ROR₅ vs. GOR

Phase 7 ROR₅ vs. GOR

Phase 8 ROR₅ vs. GOR

ROR₅ vs. GOR and/or V/C Ratio Summary (0900-1500)

Phase 1 ROR₅ vs. GOR

Phase 2 ROR₅ vs. GOR

Phase 3 ROR₅ vs. GOR

Phase 4 ROR₅ vs. GOR

Phase 5 ROR₅ vs. GOR

Phase 6 ROR₅ vs. GOR

Phase 7 ROR₅ vs. GOR

Phase 8 ROR₅ vs. GOR

Split Time Adjustment (0900-1500)

Before

Φ_1 11%	Φ_2 53%	Φ_3 16%	Φ_4 20%
Φ_5 22%	Φ_6 42%	Φ_7 16%	Φ_8 20%

After

Φ_1 11%	Φ_2 49%	Φ_3 20%	Φ_4 20%
Φ_5 22%	Φ_6 38%	Φ_7 16%	Φ_8 24%

Phase 8 Before and After Comparison (0900-1500)

Before

Phase 8 Before and After Comparison (0900-1500)

After

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

Thursday Comparison

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

Friday Comparison

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

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Very Good Progression...

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Probe Vehicle Data, the Early years

Graduate Student Powered (circa 1994)

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

		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
		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					

Before Retiming

Retiming

After Retiming

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
25	26	27	28	29	30	31

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
Week 13	25	26	27	28	29	30

Before 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	15	16	17	18
	19	20	21	22	23	24
Week 16	25	26	27	28	29	30

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): ☐ 24 one-hour periods

Corridor (right pane): ☐ 24 one-hour periods

30	US-30 EB						
	US-30 WB						
	US-31 Carmel NB						
	US-31 Carmel SB						
7	US-31 Kokomo NB						
	US-31 Kokomo SB						
14	US-36 Avon EB						
	US-36 Avon WB						
21	US-36 Pendleton Pike EB						
	US-36 Pendleton Pike WB						
28	US-40 Washington St. EB						
	US-40 Washington St. WB						
4	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						
Sun	US-52 Lafayette EB						
30	US-52 Lafayette WB						

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

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

US-31 Kokomo SB

AM Peak (0500-0900)

US-31 Kokomo NB

AM Peak (0500-0900)

Mid-Day (0900-1100)

Mid-Day (0900-1100)

Mid-Day (1100-1300)

Mid-Day (1100-1300)

Mid-Day (1300-1500)

Mid-Day (1300-1500)

PM Peak (1500-1900)

PM Peak (1500-1900)

Before

After

US-31 Kokomo SB
AM Peak (0500-0900)

US-31 Kokomo NB
AM Peak (0500-0900)

Mid-Day (0900-1100)

Mid-Day (0900-1100)

Mid-Day (1100-1300)

Mid-Day (1100-1300)

Mid-Day (1300-1500)

Mid-Day (1300-1500)

PM Peak (1500-1900)

PM Peak (1500-1900)

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

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

US-31 Kokomo SB
AM Peak (0500-0900)

US-31 Kokomo NB
AM Peak (0500-0900)

Mid-Day (0900-1100)

Mid-Day (0900-1100)

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

Mid-Day (1100-1300)

Mid-Day (1100-1300)

Mid-Day (1300-1500)

Mid-Day (1300-1500)

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

PM Peak (1500-1900)

PM Peak (1500-1900)

US-31 Kokomo SB

AM Peak (0500-0900)

US-31 Kokomo NB

AM Peak (0500-0900)

Mid-Day (0900-1100)

Mid-Day (0900-1100)

0900-1100

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

Mid-Day (1100-1300)

Mid-Day (1100-1300)

Mid-Day (1300-1500)

Mid-Day (1300-1500)

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

PM Peak (1500-1900)

PM Peak (1500-1900)

US-31 Kokomo SB

AM Peak (0500-0900)

US-31 Kokomo NB

AM Peak (0500-0900)

Mid-Day (0900-1100)

Mid-Day (0900-1100)

Mid-Day (1100-1300)

Mid-Day (1100-1300)

Mid-Day (1300-1500)

Mid-Day (1300-1500)

PM Peak (1500-1900)

PM Peak (1500-1900)

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

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

1100-1300

US-31 Kokomo SB

AM Peak (0500-0900)

US-31 Kokomo NB

AM Peak (0500-0900)

Mid-Day (0900-1100)

Mid-Day (0900-1100)

Mid-Day (1100-1300)

Mid-Day (1100-1300)

Mid-Day (1300-1500)

Mid-Day (1300-1500)

PM Peak (1500-1900)

PM Peak (1500-1900)

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

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

1300-1500

US-31 Kokomo SB

AM Peak (0500-0900)

US-31 Kokomo NB

AM Peak (0500-0900)

Mid-Day (0900-1100)

Mid-Day (0900-1100)

Mid-Day (1100-1300)

Mid-Day (1100-1300)

Mid-Day (1300-1500)

Mid-Day (1300-1500)

PM Peak (1500-1900)

PM Peak (1500-1900)

1500-1900

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

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

US-31 Kokomo SB

AM Peak (0500-0900)

US-31 Kokomo NB

AM Peak (0500-0900)

Mid-Day (0900-1100)

Mid-Day (0900-1100)

Mid-Day (1100-1300)

Mid-Day (1100-1300)

Mid-Day (1300-1500)

Mid-Day (1300-1500)

PM Peak (1500-1900)

PM Peak (1500-1900)

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

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

Apr 12

US-31 Kokomo SB

AM Peak (0500-0900)

US-31 Kokomo NB

AM Peak (0500-0900)

Mid-Day (0900-1100)

Mid-Day (0900-1100)

Mid-Day (1100-1300)

Mid-Day (1100-1300)

Mid-Day (1300-1500)

Mid-Day (1300-1500)

PM Peak (1500-1900)

PM Peak (1500-1900)

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

May 2012						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
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	6	7	8	9

May 12

US-31 Kokomo SB

AM Peak (0500-0900)

US-31 Kokomo NB

AM Peak (0500-0900)

Mid-Day (0900-1100)

Mid-Day (0900-1100)

Mid-Day (1100-1300)

Mid-Day (1100-1300)

Mid-Day (1300-1500)

Mid-Day (1300-1500)

PM Peak (1500-1900)

PM Peak (1500-1900)

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

June 2012						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
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
1	2	3	4	5	6	7

June 12

US-31 Kokomo SB

AM Peak (0500-0900)

US-31 Kokomo NB

AM Peak (0500-0900)

Mid-Day (0900-1100)

Mid-Day (0900-1100)

Mid-Day (1100-1300)

Mid-Day (1100-1300)

Mid-Day (1300-1500)

Mid-Day (1300-1500)

PM Peak (1500-1900)

PM Peak (1500-1900)

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

July 2012						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
24	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

July 12

US-31 Kokomo SB

AM Peak (0500-0900)

US-31 Kokomo NB

AM Peak (0500-0900)

Mid-Day (0900-1100)

Mid-Day (0900-1100)

Mid-Day (1100-1300)

Mid-Day (1100-1300)

Mid-Day (1300-1500)

Mid-Day (1300-1500)

PM Peak (1500-1900)

PM Peak (1500-1900)

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

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

Aug 12

US-31 Kokomo SB

AM Peak (0500-0900)

US-31 Kokomo NB

AM Peak (0500-0900)

Mid-Day (0900-1100)

Mid-Day (0900-1100)

Mid-Day (1100-1300)

Mid-Day (1100-1300)

Mid-Day (1300-1500)

Mid-Day (1300-1500)

PM Peak (1500-1900)

PM Peak (1500-1900)

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

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

Sept 12

US-31 Kokomo SB

AM Peak (0500-0900)

US-31 Kokomo NB

AM Peak (0500-0900)

Mid-Day (0900-1100)

Mid-Day (0900-1100)

Mid-Day (1100-1300)

Mid-Day (1100-1300)

Mid-Day (1300-1500)

Mid-Day (1300-1500)

PM Peak (1500-1900)

PM Peak (1500-1900)

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

October 2012						
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

Oct 12

US-31 Kokomo SB
AM Peak (0500-0900)

US-31 Kokomo NB
AM Peak (0500-0900)

Mid-Day (0900-1100)

Mid-Day (0900-1100)

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

Mid-Day (1100-1300)

Mid-Day (1100-1300)

Mid-Day (1300-1500)

Mid-Day (1300-1500)

PM Peak (1500-1900)

PM Peak (1500-1900)

Nov 12

US-31 Kokomo SB
AM Peak (0500-0900)

US-31 Kokomo NB
AM Peak (0500-0900)

Mid-Day (0900-1100)

Mid-Day (0900-1100)

Mid-Day (1100-1300)

Mid-Day (1100-1300)

Mid-Day (1300-1500)

Mid-Day (1300-1500)

PM Peak (1500-1900)

PM Peak (1500-1900)

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

US-31 Kokomo SB

AM Peak (0500-0900)

US-31 Kokomo NB

AM Peak (0500-0900)

Mid-Day (0900-1100)

Mid-Day (0900-1100)

Mid-Day (1100-1300)

Mid-Day (1100-1300)

Mid-Day (1300-1500)

Mid-Day (1300-1500)

PM Peak (1500-1900)

PM Peak (1500-1900)

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

US-31 Kokomo SB
AM Peak (0500-0900)

US-31 Kokomo NB
AM Peak (0500-0900)

Mid-Day (0900-1100)

Mid-Day (0900-1100)

Mid-Day (1100-1300)

Mid-Day (1100-1300)

Mid-Day (1300-1500)

Mid-Day (1300-1500)

PM Peak (1500-1900)

PM Peak (1500-1900)

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
---	---	---	---	---	---	---

Before Retiming

Week 13

			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

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					

Week 16

After Retiming

Arterial Retiming Cost –Benefit Analysis (monthly)

MARCH 2012

S	M	T	W	T	F	S
---	---	---	---	---	---	---

Before Retiming

Week 13

			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

S	M	T	W	T	F	S
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

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 (\$)
Southbound 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
Northbound 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)	1.26	10.0%	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%	4018.91	\$ 94,906.91	33.91	\$ 745.97
	Total		100.0%	116321.6	\$ 2,747,562	981.64	\$ 21,596.03

Arterial Retiming Cost – Benefit Analysis using Crowd Sourced Data

Plan 1 (0500-0900), SB Travel Time

Plan 1 (0500-0900), NB Travel Time

Plan 2 (0900-1100), SB Travel Time

Plan 2 (0900-1100), NB Travel Time

Plan 3 (1100-1300), SB Travel Time

Plan 3 (1100-1300), NB Travel Time

Plan 4 (1300-1500), SB Travel Time

Plan 4 (1300-1500), NB Travel Time

Plan 5 (1300-1500), SB Travel Time

Plan 5 (1300-1500), NB Travel Time

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					

Before Retiming

Week 13

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

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

Agencies Need Long-Term Documentation of Coordination Strategies

SR37 North Evaluation: 2010, 2013, 2015

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**

Changing the System Management Model

Existing Model:

New Model:

HiRes/Probe Data is a Game Changer and critical for message to decision makers