

Automated Traffic Signal Performance Measures – The Fitbit® for Your Signal System

Date: April 27, 2017
Presented by: Susan Langdon



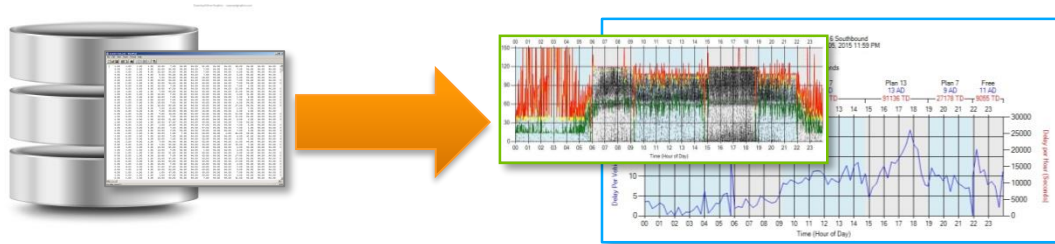
Opportunity

There are approximately 400,000 signalized intersections in the US ~ we need a systematic procedure for identifying operational problems ... and fixing them using controller and probe data.

How to Improve the Situation?



How can we get useful data from the field?



How can we get useful information from the data?

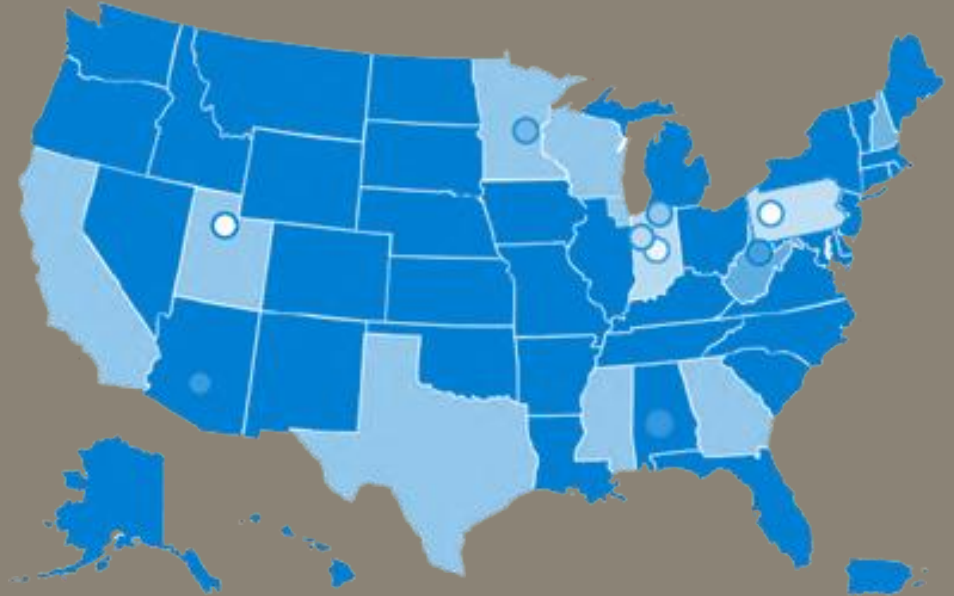


How can we leverage information to improve signal operations?

Pooled Fund Study

Participants:

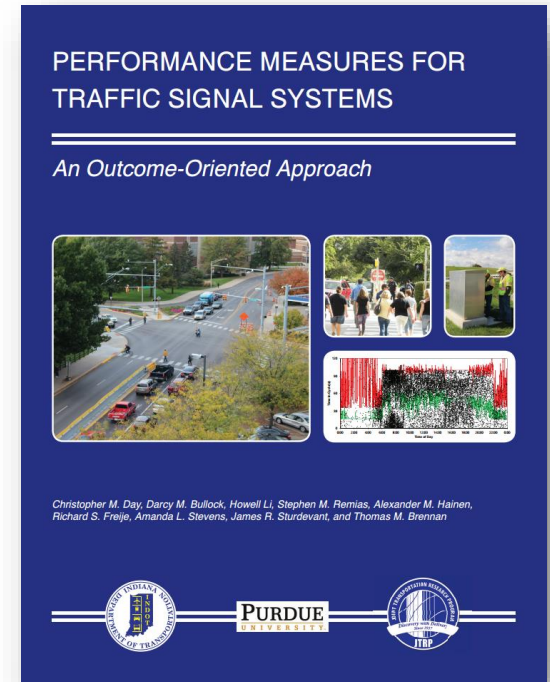
- Wisconsin DOT
- **Indiana DOT**
- Utah DOT
- City of Chicago
- Minnesota DOT
- California DOT
- New Hampshire DOT
- Texas DOT
- Mississippi DOT
- Georgia DOT
- Pennsylvania DOT
- USDOT



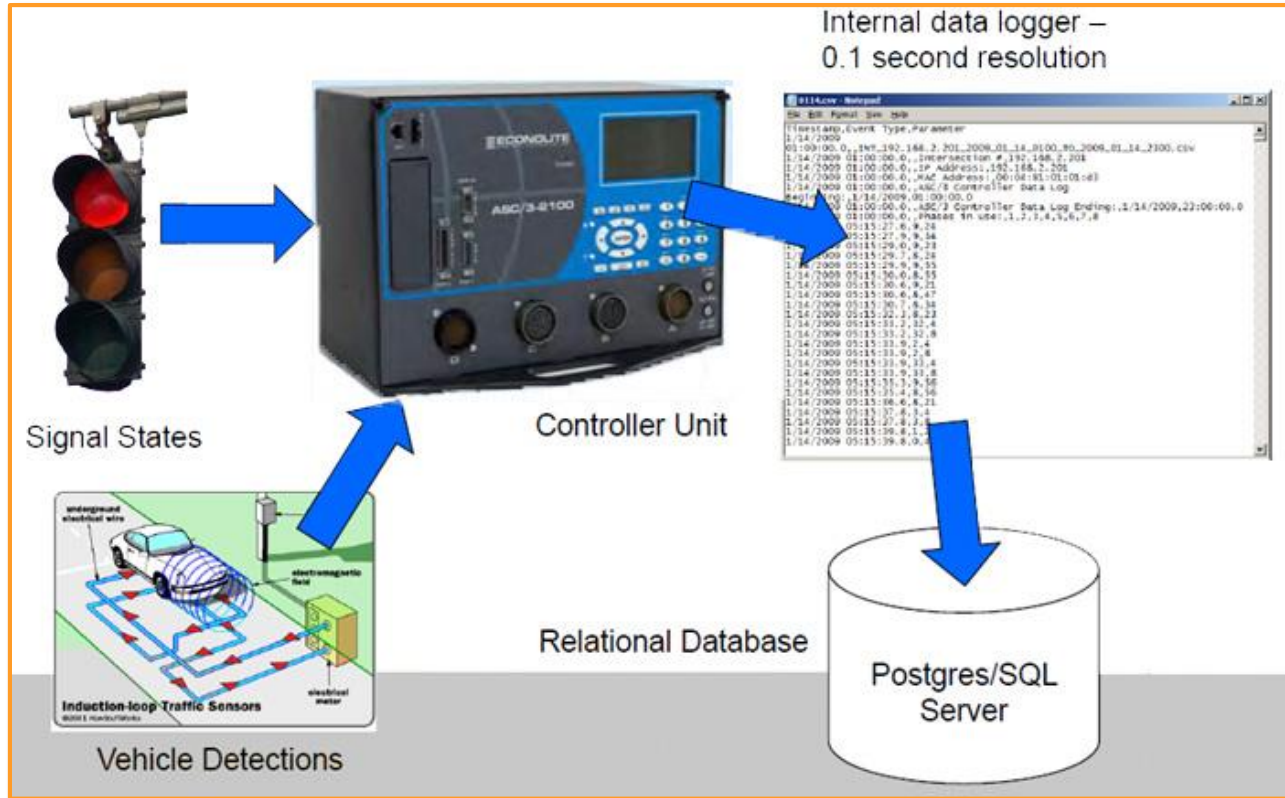
Purdue University Research

Leader in research that has led to this ability along with partners

- Purdue, INDOT and controller manufacturers collaborate to develop data logging
- Purdue develops performance measures based on data
- UDOT develops software and website to utilize the data and performance measures



High-Resolution Event Data Concept



Controller Enumerations

Event Code, Event Description, Parameter

Active Phase Events:

0	Phase On
1	Phase Begin Green
2	Phase Check
3	Phase Min Complete
4	Phase Gap Out
5	Phase Max Out
6	Phase Force Off
7	Phase Green Termination
8	Phase Begin Yellow Clearance
9	Phase End Yellow Clearance
10	Phase Begin Red Clearance
11	Phase End Red Clearance

Detector Events:

81	Detector Off
82	Detector On
83	Detector Restored
84	Detector Fault- Other
85	Detector Fault- Watchdog Fault
86	Detector Fault- Open Loop Fault

Preemption Events:

101	Preempt Advance Warning Input
102	Preempt (Call) Input On
103	Preempt Gate Down Input Received
104	Preempt (Call) Input Off
105	Preempt Entry Started

High Resolution Data

Detector 5 ON

Phase 2 BEGIN RED

Phase 8 BEGIN GREEN

06/27/2013 01:29:51.1	10	8
06/27/2013 01:29:51.1	82	5
06/27/2013 01:29:52.2	1	2
06/27/2013 01:29:52.2	1	6
06/27/2013 01:29:52.3	82	2
06/27/2013 01:29:52.8	82	4
06/27/2013 01:29:52.9	81	4
06/27/2013 01:29:53.3	81	6
06/27/2013 01:29:54.5	81	2
06/27/2013 01:30:02.2	8	2
06/27/2013 01:30:02.2	8	6
06/27/2013 01:30:02.2	33	2
06/27/2013 01:30:02.2	33	6
06/27/2013 01:30:02.2	32	2
06/27/2013 01:30:02.2	32	6
06/27/2013 01:30:06.1	10	2
06/27/2013 01:30:06.1	10	6
06/27/2013 01:30:08.1	1	8
06/27/2013 01:30:13.1	32	8
06/27/2013 01:30:15.8	81	5
06/27/2013 01:30:18.5	82	6

HOW'S THE
BIG DATA PROJECT
COMING ALONG,
HOSKINS?



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How Does It Work?



Controller with high-resolution data logging



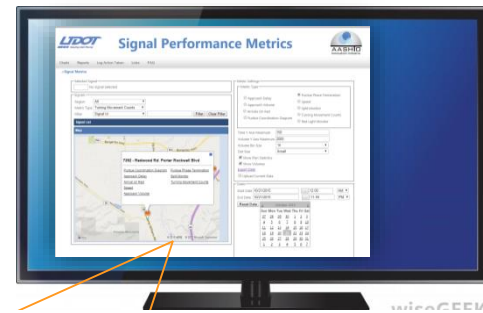
Communication



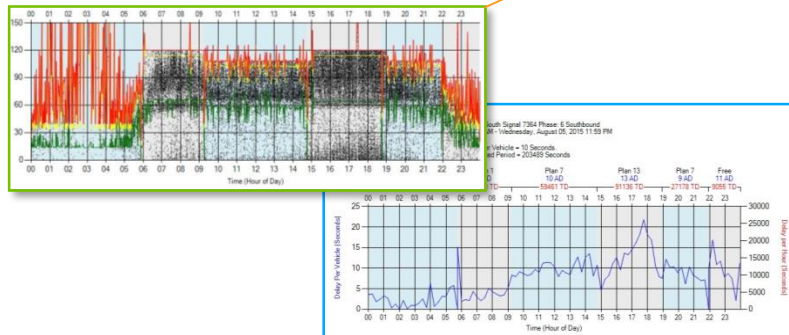
Server receives / stores data files



Query Data



Website software queries server data and displays as graphs



System Requirements

- **High-resolution data logging controller**
- **Detection**
- **Communication**
- **Server**
- **Website**

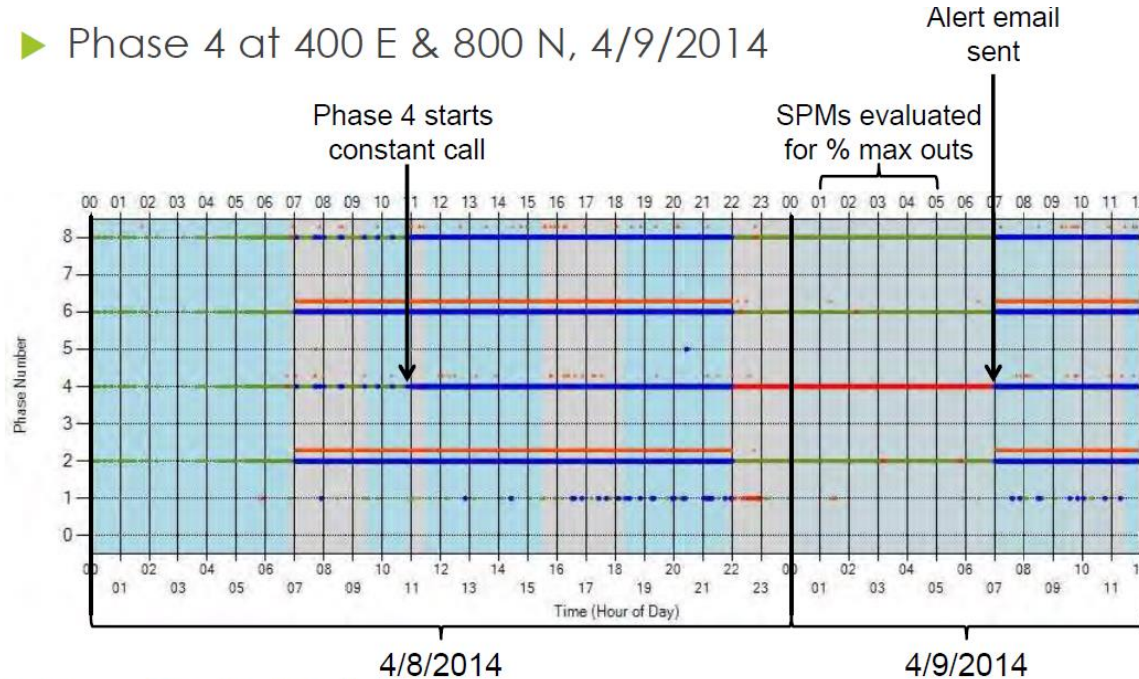
Does NOT require Central Traffic Management Software

Types of Performance Measures

- **Purdue Phase Termination**
- **Split Monitor**
- **Purdue Coordination Diagram**
- **Approach Delay**
- **Purdue Split Failure**
- **Purdue Link Pivot**
- **Pedestrian Delay**
- **Preemption Details**
- **Turning Movement Count**
- **Approach Volume**
- **Arrivals on Red**
- **Approach Speed**
- **Yellow and Red Actuations**

Phase Termination

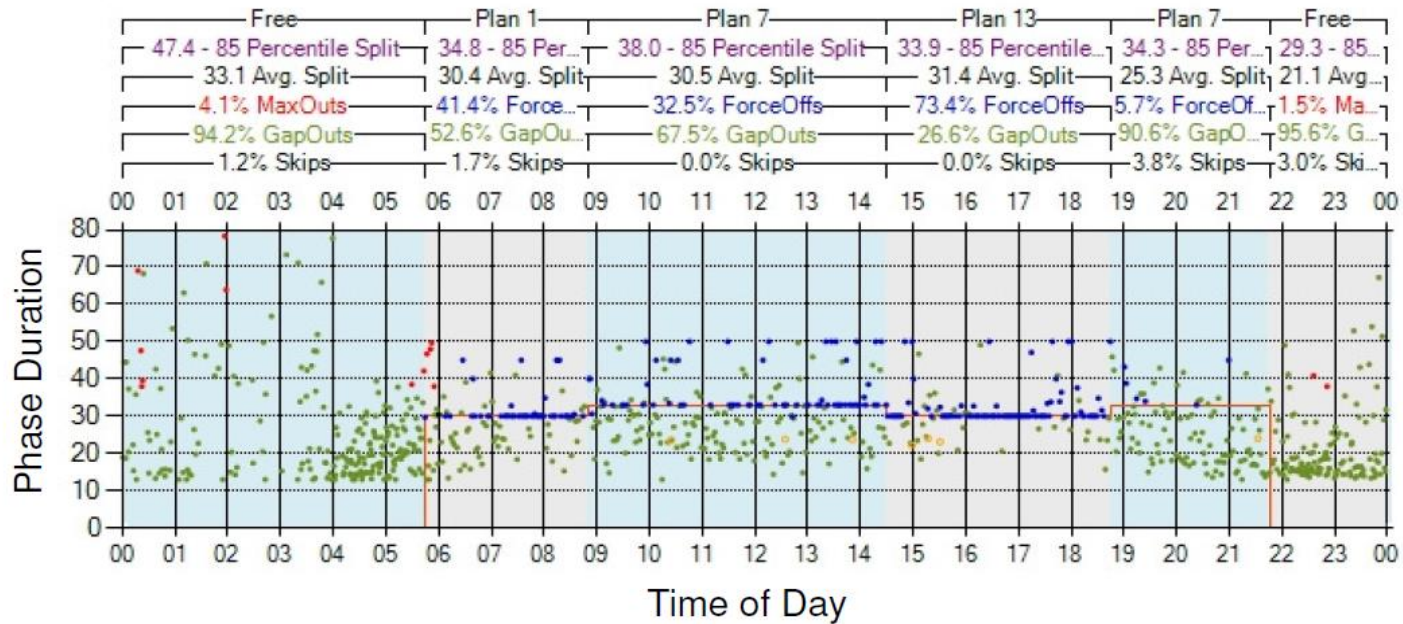
► Phase 4 at 400 E & 800 N, 4/9/2014



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

Split Monitor

US-89 2700 North SIG#5372 Phase 6
 Wednesday, March 09, 2016 12:00 AM - Thursday, March 10, 2016 12:00 AM



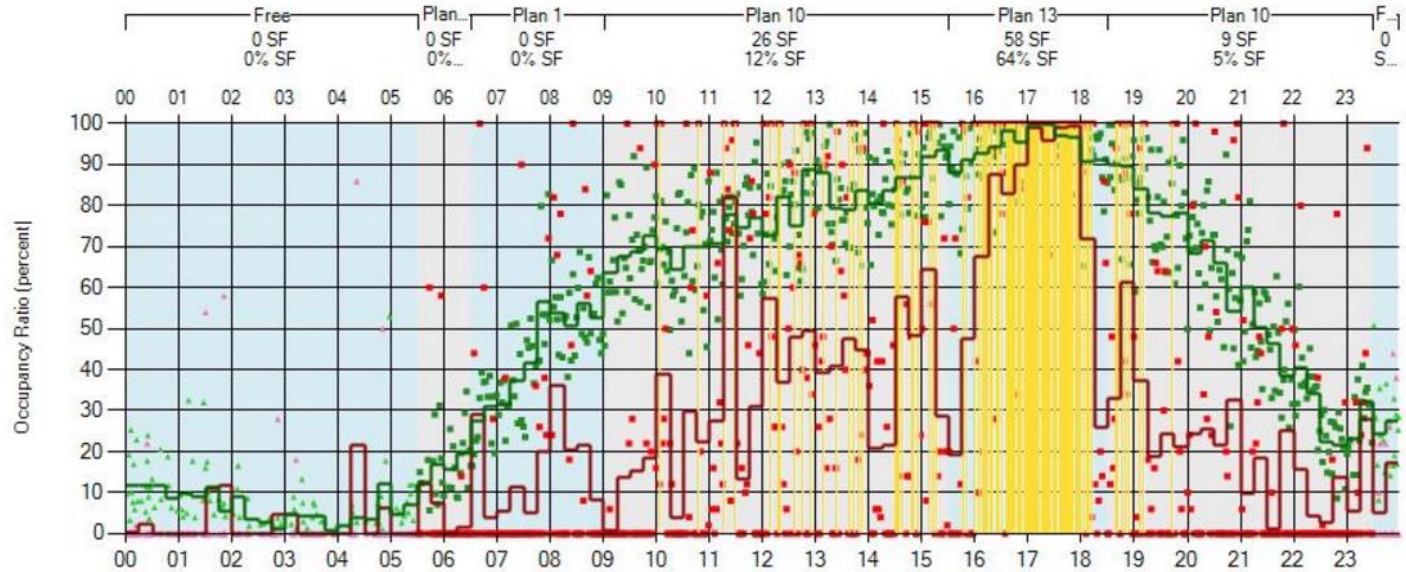
Purdue Split Failure

700 East @ 900 South - SIG#7184
Wednesday, April 27, 2016 12:00 AM - Wednesday, April 27, 2016 11:59 PM

Protected Phase 6: Southbound Thru

Total Split Failures = 93

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

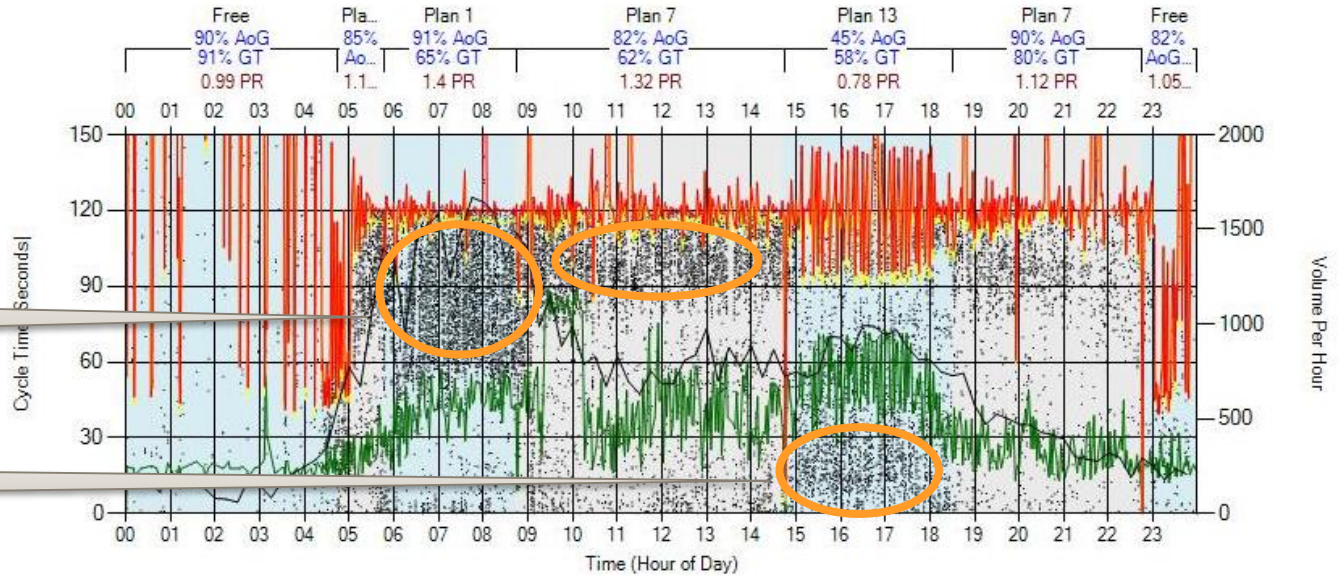


Purdue Coordination Diagram

Bangerter Hwy (SR-154) 2400 South Signal 7057 Phase: 2 Northbound
 Monday, March 14, 2016 12:00 AM - Monday, March 14, 2016 11:59 PM

78% AoG

- Detector Activation
- Change to Green
- Change to Yellow
- Change to Red
- Volume Per Hour
- AoG - Arrival On Green
- GT - Green Time
- PR - Platoon Ratio



Arrivals during green

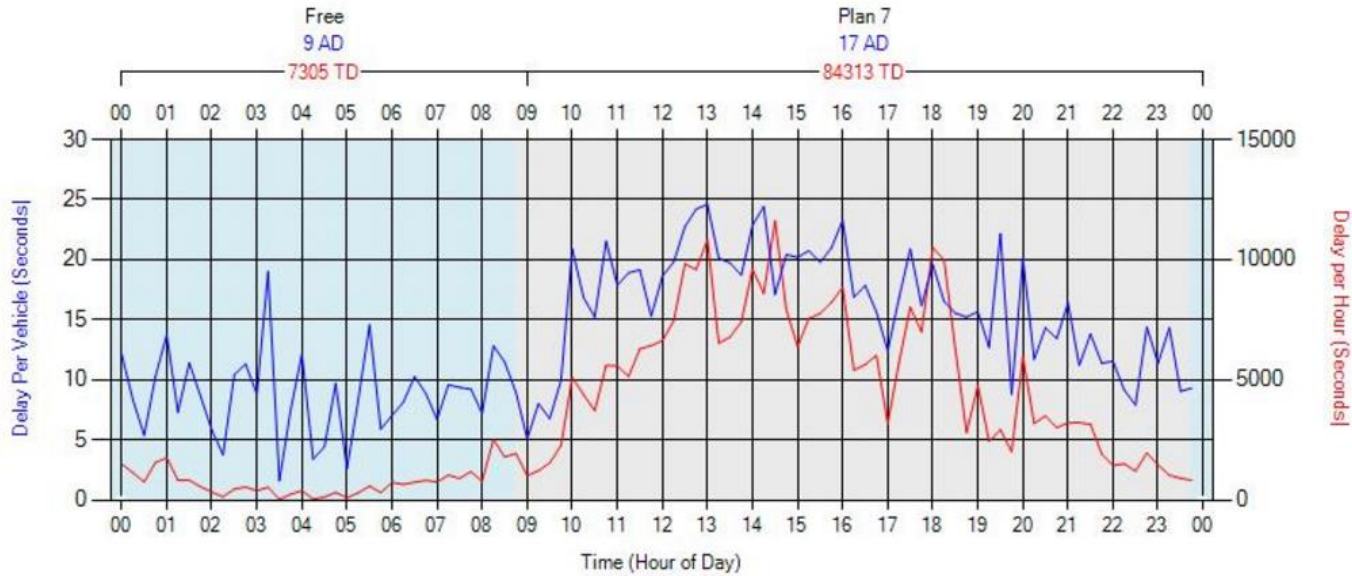
Arrivals before green

Approach Delay

State Street @ 7200 South - SIG#7168
Sunday, May 29, 2016 12:00 AM - Sunday, May 29, 2016 11:59 PM

Phase 2: Northbound

Average Delay Per Vehicle (AD) = 16 seconds; Total Delay For Selected Period (TD) = 91617 seconds



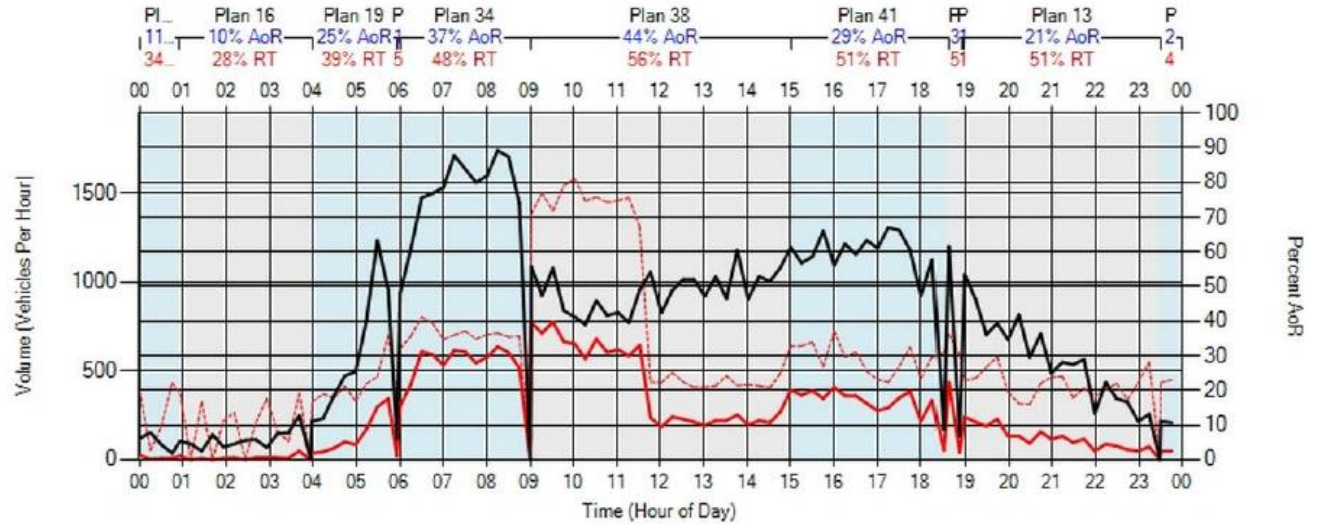
Simplified Approach Delay. Displays time between approach activation during the red phase and when the phase turns green.
Does NOT account for start up delay, deceleration, or queue length that exceeds the detection zone.

Arrivals on Red

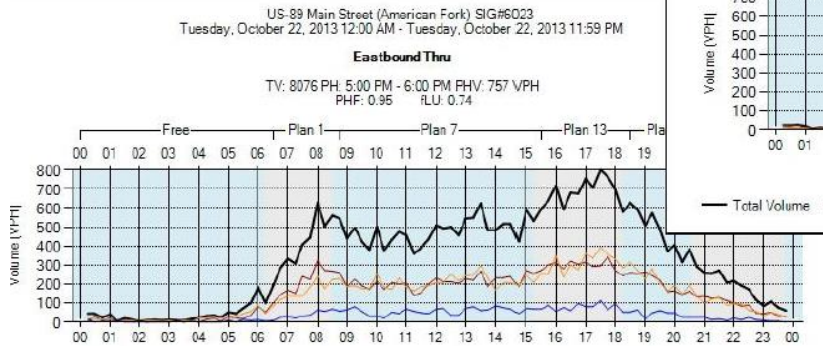
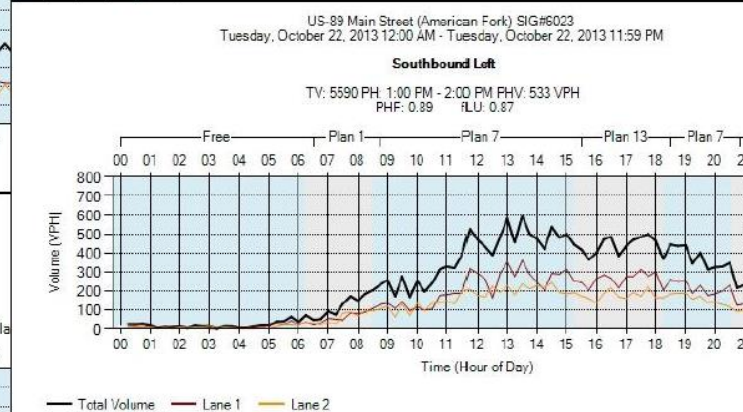
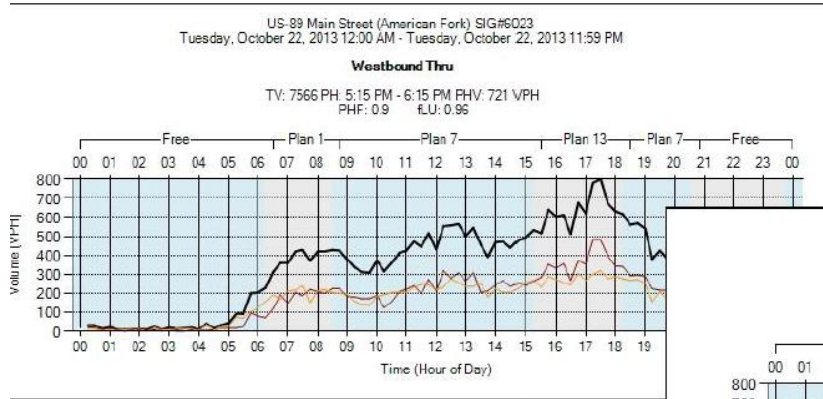
Bangerter Hwy (SR-154) 5400 South (SR-173) Signal 7063 Overlap: 10 Northbound
 Thursday, March 07, 2013 12:00 AM - Thursday, March 07, 2013 11:59 PM

Total Detector Hits = 18979 Total AoR = 6422
 Percent AoR for the select period = 34

- Arrivals on Red
- - - Percent Arrivals on Red
- Total Vehicles

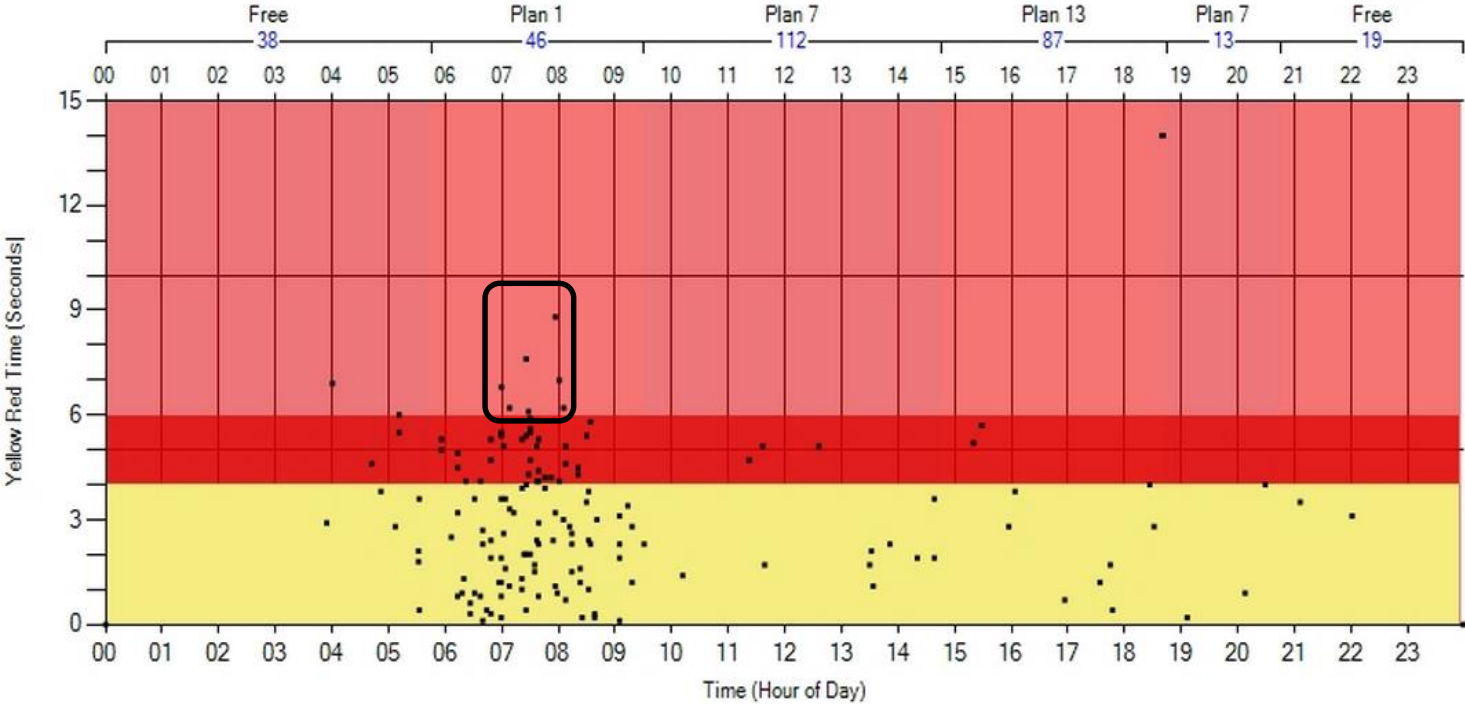


Turning Movement Counts



Red Light Monitoring


5600 West 2700 South Signal 7379 Phase: 4 Eastbound
Monday, May 18, 2015 12:00 AM - Monday, May 18, 2015 11:59 PM



Alerts

- Daily email at 7 am
- Uses Purdue Phase Termination chart data
- Flags phases with $> 90\%$ max-outs on each phase between 1 am and 5 am
- Compare to previous day's list; only phases with new flags are sent in email

SPM Alerts for 4/9/2014

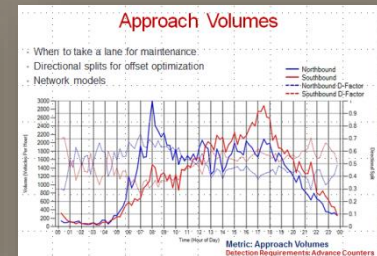
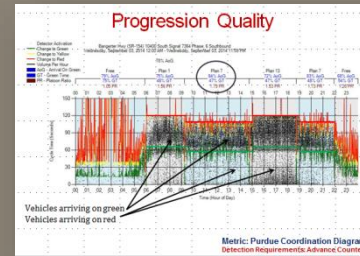
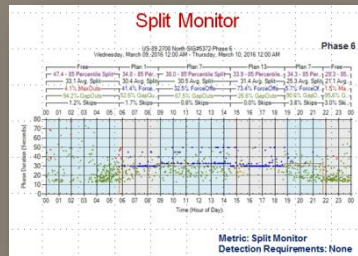
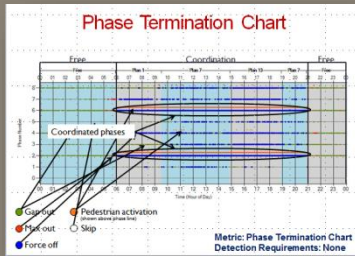
 **SPMWatchDog@utah.gov**

- 5092 - SR-126 (1900 W) & Riverdale (5300 S) (Roy) - Phase: 1
- 5105 - Antelope (SR-108/2000 N) & I-15 NB (Layton) - Phase: 4
- 6022 - US-89 & Pacific Dr (American Fork) - Phase: 3
- 6305 - 400 East & 800 North - Phase: 4 ← Example
- 6310 - Center Street (Orem) & I-15 SPUI - Phase: 8
- 7055 - Bangerter Hwy (SR-154) & SR-201 DDI - Phase: 5
- 7062 - Bangerter Hwy (SR-154) & 4700 South - Phase: 11
- 7613 - 10600 South & 700 West - Phase: 8
- 8114 - Bluff Street & I-15 NB Ramps - Phase: 4

Engineers can now
directly measure
what previously
could only *estimate*
and model

What can Automated Signal Performance Measures do for you?

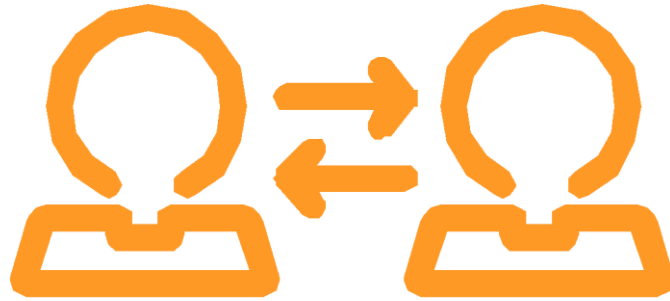
- Troubleshoot complaints and reduce wasted time for maintenance staff
- Identify problems more quickly – without waiting for the complaint call
- Operate & optimize system more efficiently
- Retime signals as needed, not on a schedule
- Communicate system performance to public & agency leaders
- Transition from reactive management to proactive signal management
- Truly **MEASURE** system performance



Future of Performance Measures?

- UDOT software is available on the FHWA Open Source Application Development Portal (OSADP)
<http://www.itsforge.net>
- GDOT provided documentation for installation and use of the UDOT software
- Every Day Counts-4 Regional Summits late Fall 2016 – ATSPMs major focus
 - https://www.fhwa.dot.gov/innovation/everydaycounts/edc_4/
- FAST Act funding – Advanced Transportation and Congestion Management Technologies Deployment
<http://www.fhwa.dot.gov/fastact/factsheets/advtranscongmgmtfs.cfm>

Questions?

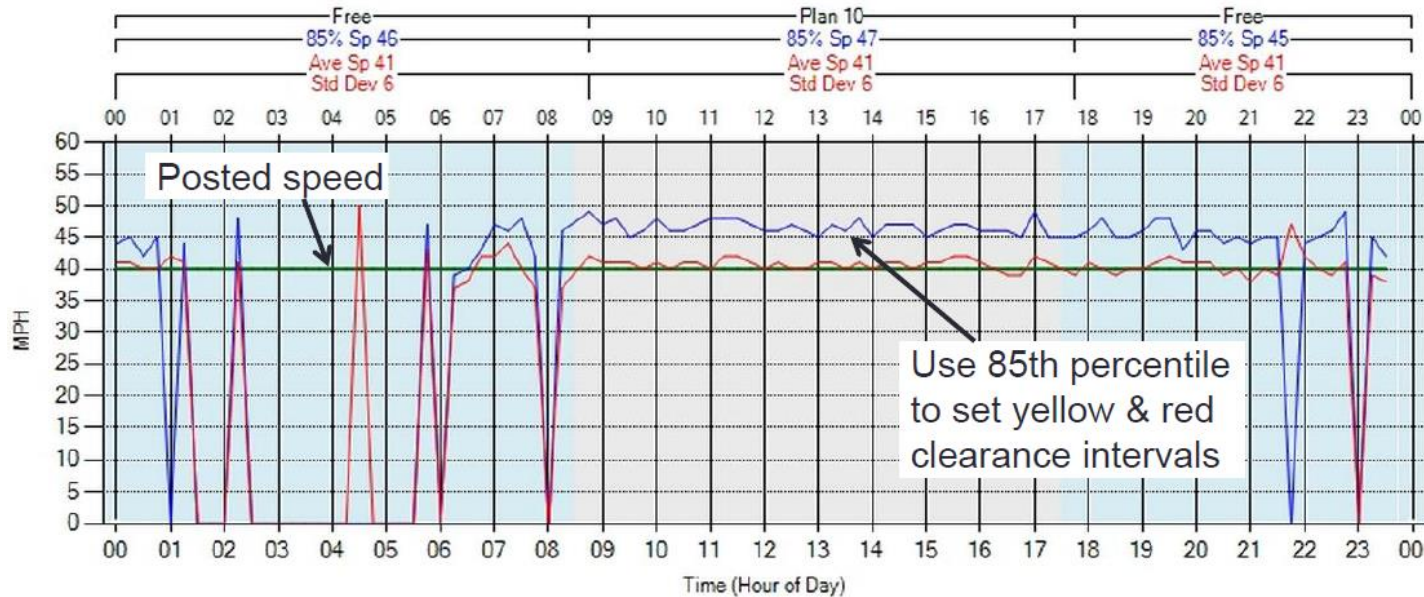


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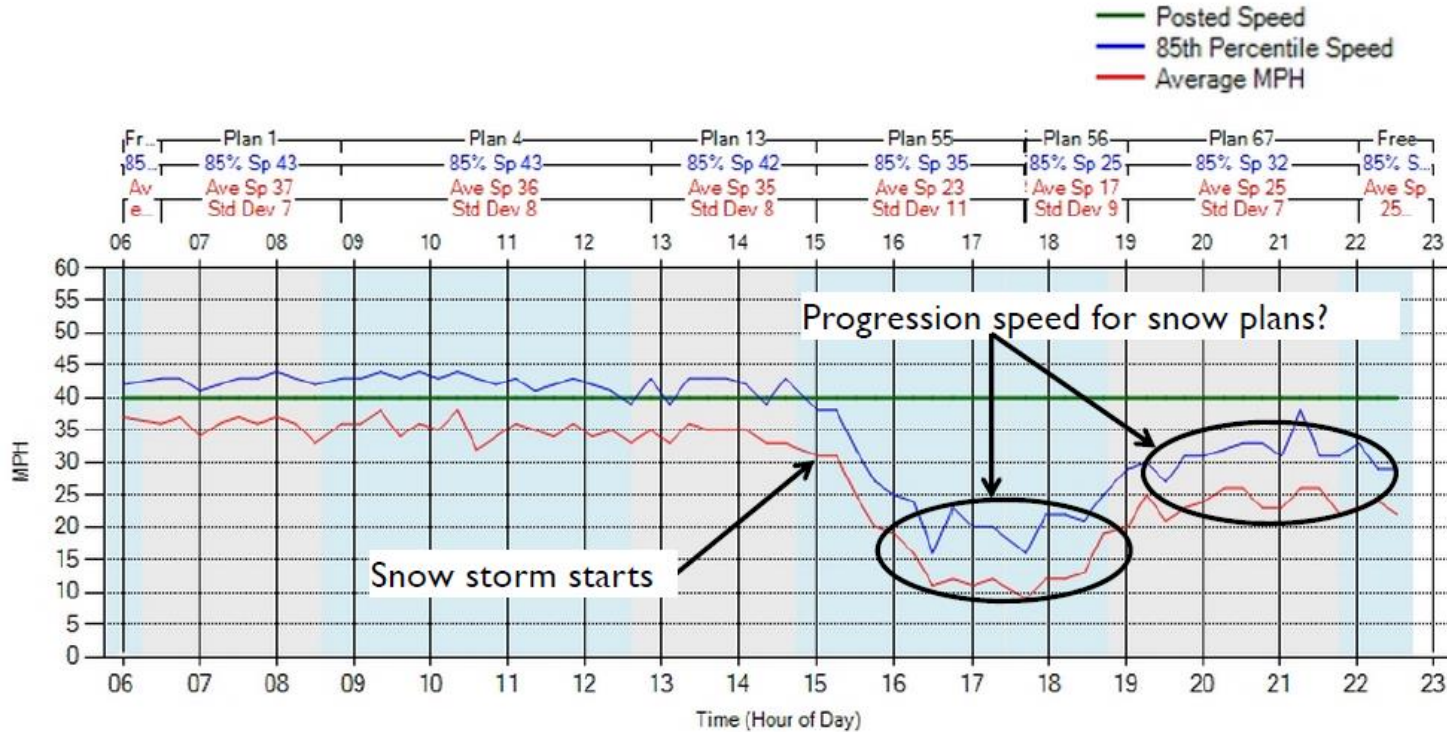
Approach Speed

Bluff & 100 S, St. George, NB (5/5/2013)

— Posted Speed
— 85th Percentile Speed
— Average MPH



Approach Speed



Offset Optimization Using Link Pivot Algorithm

<https://www.youtube.com/watch?v=Yf1ZtDA8Edw>



Executive Reports & Prioritizing

Are signal operations improving, staying same or declining? By how much?
How does agency most effectively priority resources and workload?

What are areas of most need?

Regional, corridor and intersection summaries available.

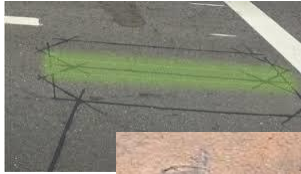
System Requirements



- Econolite cobalt – any version
- Econolite ASC3 – v2.50+ & OS 1.14.03+
- Econolite 2070 with 1C CPU Module V32.50+
- Intelight Maxtime V 1.7.0+
- Peek ATC Greenwave 03.05.0528+
- Trafficware 980ATCV 76.10+
- Siemens M50 Linux & M60 ATC (ecom v 3.5+, NTCIP V4.5+)
- McCain ATC Omni eX 1.6+

System Requirements

Detection



Any detection will work - loops, pucks, video, radar.

Speed metric requires radar detection.



System Requirements

Communication



Can be accomplished in many ways, including fiber optic cable, wireless radio, cable or telephone providers, cell modem, satellite, twisted wire pair, even site visit to manually download.

System Requirements

Operating Systems and Software

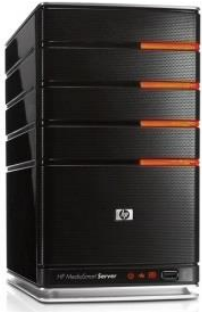


The software runs on Microsoft Windows Servers.

The database server is a Microsoft SQL 2008 or later; large systems will require Enterprise Edition.

System Requirements

Storage and Processing Requirements



Detector data uses about 60% of the storage space, so the number of detectors attached to a controller will have a significant impact on the amount of storage space required.

Data storage will require approximately 12 MB per controller per day for 8 phase operation with detection on all approaches.

System Requirements

Website



Signal Performance Metrics



Charts Reports Log Action Taken Links FAQ

->Signal Metrics

Selected Signal
No Signal Selected

Signals
Region: All
Metric Type: All
Filter: Signal Id [] Filter Clear Filter

Signal List

Map

Metric Settings

Metric Type

- Purdue Phase Termination
- Split Monitor
- Pedestrian Delay
- Preemption Details
- Turning Movement Counts
- Purdue Coordination Diagram
- Approach Volume
- Approach Delay
- Arrivals On Red
- Approach Speed
- Yellow and Red Actuations
- Purdue Split Failure

Time Y Axis Maximum: 150
Volume Y Axis Maximum: 2000
Volume Bin Size: 15
Dot Size: Small

Show Plan Statistics
 Show Volumes
[Export Data](#)
 Upload Current Data

Dates
Start Date: 7/30/2016 12:00 AM
End Date: 7/30/2016 11:59 PM

Reset Date

July 2016						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
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	6

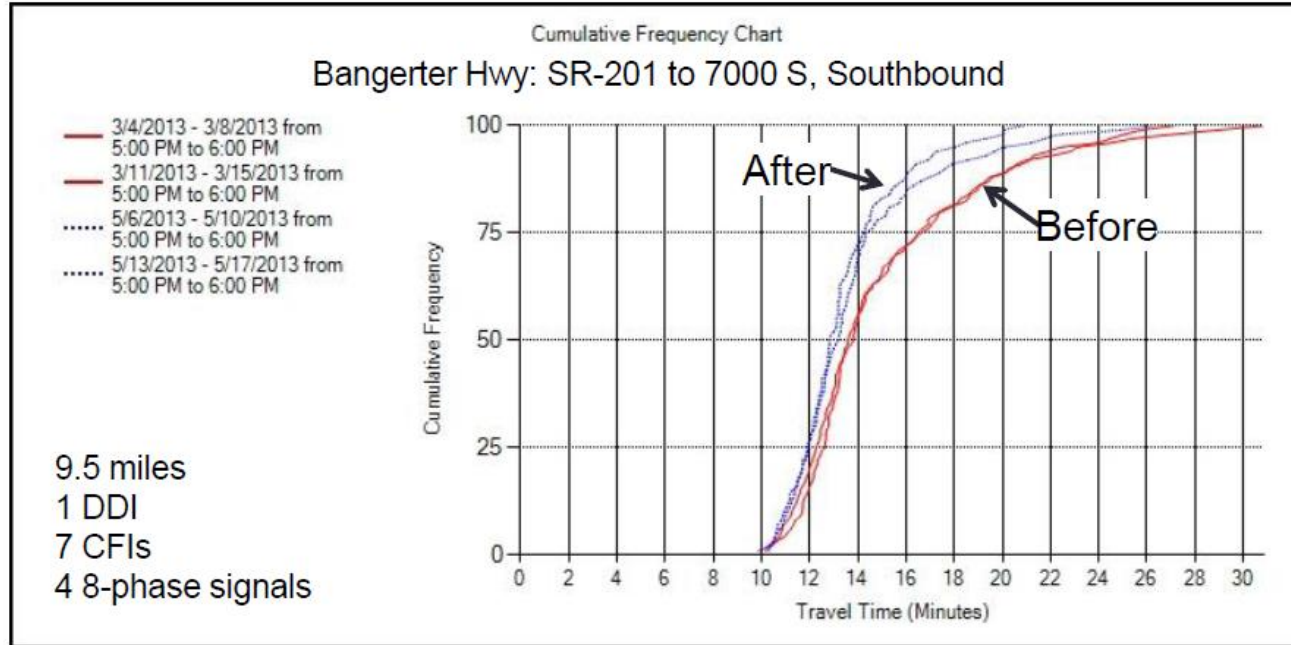
Create Metrics

Version 3.1.5. Release Date: May 2016

<http://udottraffic.utah.gov/signalperformancemetrics/>



Purdue Travel Time

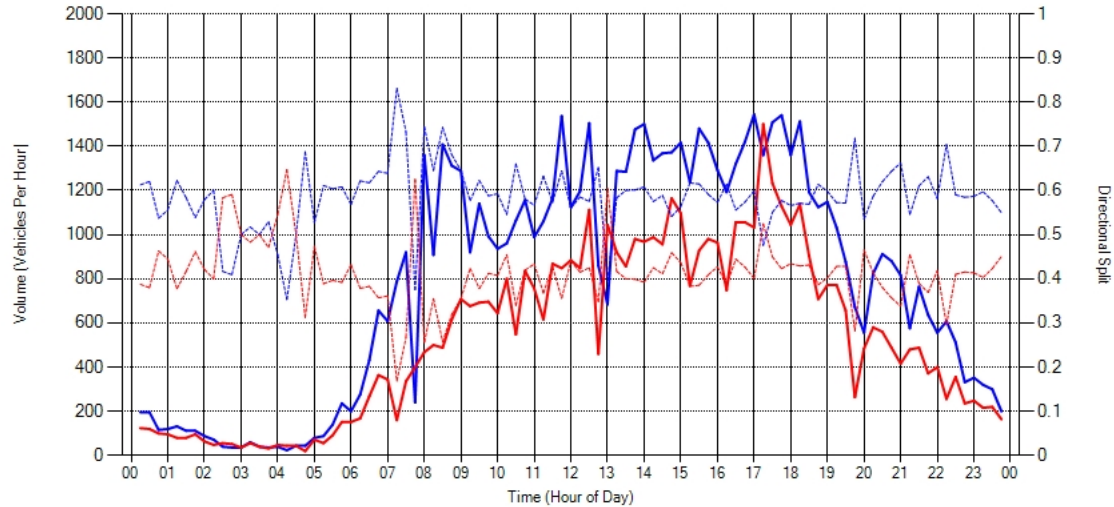


Approach Volumes

Stop Bar Detection

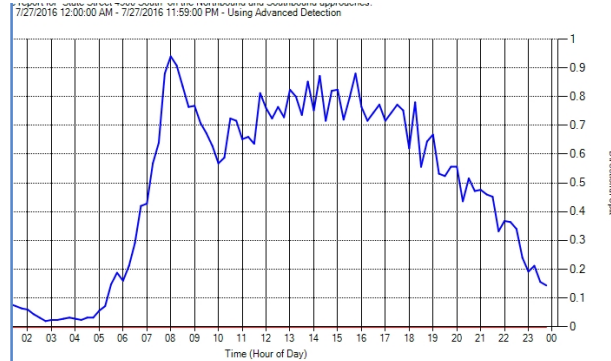
Volume report for State Street 4500 South on the Northbound and Southbound approaches.
7/27/2016 12:00:00 AM - 7/27/2016 11:59:00 PM - Using Stop Bar Detection

- Northbound
- Southbound
- Northbound D-Factor
- Southbound D-Factor

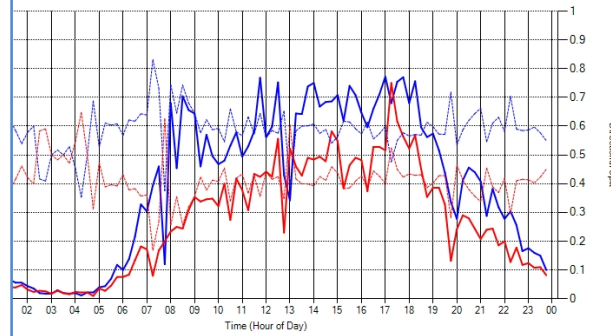


Approach Volumes

Stop Bar and Approach Detection



Report for State Street 4500 South on the Northbound and Southbound approaches.
7/27/2016 12:00:00 AM - 7/27/2016 11:59:00 PM - Using Stop Bar Detection

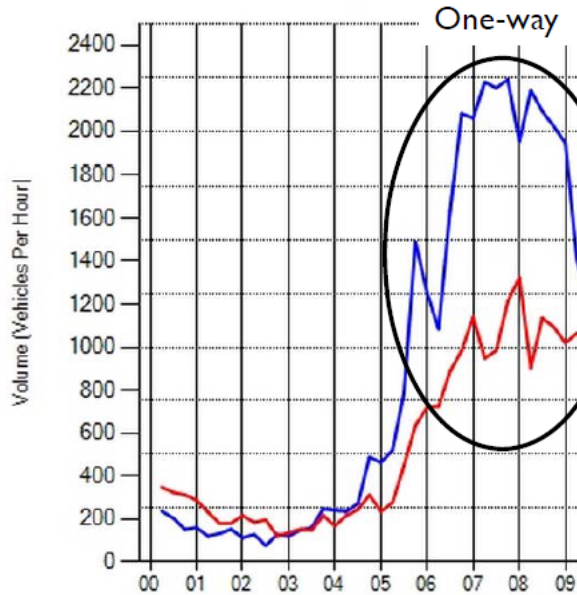


Metric	Value
Total Volume	11,440
Peak Hour	7:45 AM - 8:45 AM
Peak Hour Volume	891
PHF	0.948
Peak-Hour K-factor	0.0779
Northbound Total Volume	11,440
Northbound Peak Hour	7:45 AM - 8:45 AM
Northbound Peak Hour Volume	891
Northbound PHF	0.948
Northbound Peak-Hour K-factor	0.0779
Northbound Peak-Hour D-factor	NaN
Southbound Total Volume	0
Southbound Peak Hour	12:00 AM - 1:00 AM
Southbound Peak Hour Volume	0
Southbound PHF	0
Southbound Peak-Hour K-factor	NaN
Southbound Peak-Hour D-factor	0

Metric	Value
Total Volume	31,156
Peak Hour	5:00 PM - 6:00 PM
Peak Hour Volume	2,711
PHF	0.948
Peak-Hour K-factor	0.087
Northbound Total Volume	18,544
Northbound Peak Hour	5:00 PM - 6:00 PM
Northbound Peak Hour Volume	1,488
Northbound PHF	0.964
Northbound Peak-Hour K-factor	0.0802
Northbound Peak-Hour D-factor	0.822
Southbound Total Volume	12,612
Southbound Peak Hour	5:15 PM - 6:15 PM
Southbound Peak Hour Volume	1,226
Southbound PHF	1
Southbound Peak-Hour K-factor	0.0972
Southbound Peak-Hour D-factor	1.18

Coordination: Progression Type

Metric: Approach Volume



Metric	Value
Total Volume	47,646
Peak Hour	5:00 PM - 6:00 PM
Peak Hour Volume	3,561
PHF	0.988
Peak-Hour K-factor	0.0747
Northbound Total Volume	24,634
Northbound Peak Hour	7:00 AM - 8:00 AM
Northbound Peak Hour Volume	2,182
Northbound PHF	0.974
Northbound Peak-Hour K-factor	0.0886
Northbound Peak-Hour D-factor	0.491
Southbound Total Volume	23,012
Southbound Peak Hour	4:15 PM - 5:15 PM
Southbound Peak Hour Volume	2,003
Southbound PHF	1
Southbound Peak-Hour K-factor	0.087
Southbound Peak-Hour D-factor	0.701

Link Pivot Algorithm

- Based on the validated prediction methodology, we devised a way to systematically adjust offsets to find an optimal solution...

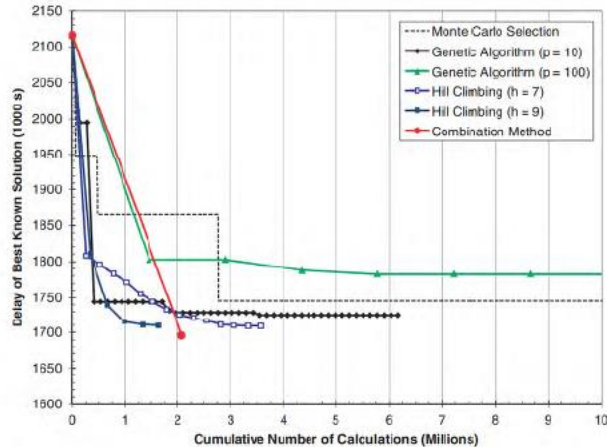


FIGURE 6 Performance of alternative methodologies for offset optimization.

Computational Efficiency of Alternative Algorithms for Arterial Offset Optimization

Christopher M. Day and Darcy M. Bullock

This paper compares the performance of several algorithms for offset optimization. A case study of a five-intersection arterial is presented. Cycle probability distributions of vehicle arrivals and the probability of green are used to characterize traffic conditions and allocation effects. Five algorithms for offset optimization were selected for comparison: sequential search, Monte Carlo selection, genetic algorithms, hill climbing, and the combination method. Each algorithm was evaluated with two chromosome algorithms: sequential delay and maximum vehicle arrival on green. The relative performance of the algorithms were characterized by the optimality of the solution that they returned, the number of computations needed to execute the algorithm, and the amount of time of adding an additional intersection to the system. All five algorithms effectively identified optimal or near-optimal offset within the solution space. Hill climbing was more efficient than sequential search, but the optimality of the solution from both types was similar. The combination method found the most optimal offset, with additional similar results of hill climbing. The combination method is recommended for arterial offset optimization because of its demonstrated computational performance for identifying optimal offset using genes.

The selection of offsets in traffic signal timing plans is critical for establishing vehicle progression. As present traffic engineers are a smaller, more specialized group of software programmers for designing and timing signal timing plans, which rely on their own in-house hard-coded algorithms. Although there is a considerable literature comparing the performance of these software packages against each other and proposed methods, less attention has been paid to the relative performance of the internal algorithms. This paper explicitly compares the performance of alternative algorithms in an arterial traffic model. Recently, the introduction of online data collection into traffic signal controller firmware has allowed signal centers to be large in size and time to the highest possible state resolution (1). This paper describes a methodology for offset optimization with high resolution controller data and compares the performance of alternative algorithms for optimizing offset in that model. A queue-calculator-based, Monte Carlo selection, the combination method, hill climbing, and genetic algorithms (GA) are compared. The paper concludes with some observations that the combination method is well to optimize offsets where possible, because of its computational efficiency and robust performance.

Purdue University, 565 Station Mall Drive, West Lafayette, IN 47906. Corresponding author: C. M. Bullock, cbullock@iastate.edu.
Transportation Research Board, Journal of the Transportation Research Board, No. 2259, Transportation Research Board of the National Academies, Washington, D.C., 2003, pp. 37-47.
DOI: 10.1002/2050

BACKGROUND

Offset optimization can be described as a mathematical optimization problem in which the admissible parameters are the offsets and the objective is to minimize an economic performance measure that is a complex function of these parameters. In a network of n signals, the number of possible offset combinations is generally $(24)^n$, where 24 is the cycle length (s) and 4 is the number of offsets for the search. The complexity of the problem increases exponentially with n , making it essential to adopt efficient optimization techniques. Table 1 lists advantages and disadvantages of various mathematical techniques for the offset optimization problem for delay minimization (2). The quasi-sequential search and Monte Carlo solutions are heuristic strategies for sampling a large solution space. A quasi-sequential search is an exhaustive search using a value of r that makes $(24)^n$ "computationally tractable." Monte Carlo selection samples the solution space by random selection of parameters over many iterations. As more iterations are accumulated, the best known parameter combination continues to improve. However, no knowledge of the performance of past parameters is used to aid the selection of new ones. Heuristic optimization methods leverage the performance of past iterations. In this paper, hill climbing and GA are considered.

- In hill climbing, a vector of full clock increments is applied to each offset; the next optimal increment is retained. It is carried out for one intersection at a time from iterative loop that repeats until the system performance cannot be improved further.
- In GA, the parameters are coded as genetic sequences and are manipulated in a simulation of the behavior of DNA, during reproduction (3). The first generation is a population of randomly generated parameters. Subsequent generations are created from the fitness results of previous generations, with random changes (mutation) during crossover and recombination, inspected as improvements of the encoded parameters. An overview is presented by Jones (4). For example, the first used GA for signal timing design, numerous subsequent implementations compare GA against other optimization methods in a variety of applications with the results tabulating (5-9). Thus, GA appears to have potential for future software implementation. GA has been implemented in recent versions of TRANSYT.

The combination method leverages information about the network topology to optimize offsets (11, 12). Parallel combinations of link flows are a part of every link flow (and are implicitly are combined by adding up their individual delay) rather than offsets. So, the combination method connects queues that experience a single flow. As subsequent series combinations accumulate, previously optimized link flows are linked, thereby by adjusting the combined offset as a group to accommodate the newly combined link. The final combination

