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

FDOT 2017 Design Training Expo
June 6, 2017
Presented by: Susan Langdon, PE, PTOE
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 do we implement real-time monitoring of system health and quality of operation?
Causes of Poor Traffic Signal Operation

- Budget and personnel constraints
  - Limited funding for signal timing projects
  - Lack of dedicated signal operations staff

- Lack of information from the field
  - Manual data collection
  - Software modeling
  - Limited data coverage
Scale of the Problem

- What intersections are experiencing operational deficiencies?
- What movements at the intersection?
- What times of day?
- What days of week?
- Recurring or non-recurring?
- What type of problem?
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
## Controller Enumerations

**Event Code, Event Description, Parameter**

<table>
<thead>
<tr>
<th>Active Phase Events:</th>
<th>Detector Events:</th>
</tr>
</thead>
<tbody>
<tr>
<td>0   Phase On</td>
<td>81 Detector Off</td>
</tr>
<tr>
<td>1   Phase Begin Green</td>
<td>82 Detector On</td>
</tr>
<tr>
<td>2   Phase Check</td>
<td>83 Detector Restored</td>
</tr>
<tr>
<td>3   Phase Min Complete</td>
<td>84 Detector Fault- Other</td>
</tr>
<tr>
<td>4   Phase Gap Out</td>
<td>85 Detector Fault- Watchdog Fault</td>
</tr>
<tr>
<td>5   Phase Max Out</td>
<td>86 Detector Fault- Open Loop Fault</td>
</tr>
<tr>
<td>6   Phase Force Off</td>
<td></td>
</tr>
<tr>
<td>7   Phase Green Termination</td>
<td></td>
</tr>
<tr>
<td>8   Phase Begin Yellow Clearance</td>
<td></td>
</tr>
<tr>
<td>9   Phase End Yellow Clearance</td>
<td></td>
</tr>
<tr>
<td>10  Phase Begin Red Clearance</td>
<td></td>
</tr>
<tr>
<td>11  Phase End Red Clearance</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Preemption Events:</th>
</tr>
</thead>
<tbody>
<tr>
<td>101 Preempt Advance Warning Input</td>
</tr>
<tr>
<td>102 Preempt (Call) Input On</td>
</tr>
<tr>
<td>103 Preempt Gate Down Input Received</td>
</tr>
<tr>
<td>104 Preempt (Call) Input Off</td>
</tr>
<tr>
<td>105 Preempt Entry Started</td>
</tr>
<tr>
<td>Date/Time</td>
</tr>
<tr>
<td>--------------------</td>
</tr>
<tr>
<td>05/27/2013 01:29:51.1</td>
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<tr>
<td>05/27/2013 01:29:51.1</td>
</tr>
<tr>
<td>05/27/2013 01:29:52.2</td>
</tr>
<tr>
<td>05/27/2013 01:29:52.2</td>
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<tr>
<td>05/27/2013 01:29:52.3</td>
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<tr>
<td>05/27/2013 01:29:52.8</td>
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<tr>
<td>05/27/2013 01:29:52.9</td>
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<tr>
<td>05/27/2013 01:29:53.3</td>
</tr>
<tr>
<td>05/27/2013 01:29:54.5</td>
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<tr>
<td>05/27/2013 01:30:02.2</td>
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<tr>
<td>05/27/2013 01:30:02.2</td>
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<td>05/27/2013 01:30:02.2</td>
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<td>05/27/2013 01:30:02.2</td>
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<tr>
<td>05/27/2013 01:30:08.1</td>
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<td>05/27/2013 01:30:08.1</td>
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<td>05/27/2013 01:30:08.1</td>
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<td>05/27/2013 01:30:13.1</td>
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<tr>
<td>05/27/2013 01:30:15.8</td>
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<tr>
<td>05/27/2013 01:30:18.5</td>
</tr>
</tbody>
</table>
How's the big data project coming along, Hoskins?
How Does It Work?

The Basic Concept

Controller with high-resolution data logging

Communication

Server receives / stores data files

Query Data

Website software queries server data and displays as graphs

Does NOT require Central Traffic Management Software
System Requirements

- High Resolution Controller
- Communications
- Server
- Website
- Detection
System Requirements

Controllers

- 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 980ATC V 76.10+
- Siemens M50 Linux & M60 ATC (ecom v 3.5+, NTCIP V4.5+)
- McCain ATC Omni eX 1.6
System Requirements

Communication

Can be accomplished in many ways, including fiber optic cable, wireless, cable or telephone providers, cell modem, satellite, twisted wire pair, even site visit to manually download from external storage (ie Raspberry Pi).
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 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

Detection

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

Speed metric requires radar detection
## Performance Measures

<table>
<thead>
<tr>
<th>Measure</th>
<th>No Detection</th>
<th>Setback count (350-400 ft)</th>
<th>Setback count (350-400 ft) using radar</th>
<th>Stop bar (lane by lane)</th>
<th>Probe (GPS or Bluetooth)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purdue Coordination Diagram</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
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<tr>
<td>Approach Volume</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Approach Speed</td>
<td>✔️</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purdue Phase Termination</td>
<td>✔️</td>
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</tr>
<tr>
<td>Split Monitor</td>
<td>✔️</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Turning Movement Counts</td>
<td>✔️</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Approach Delay</td>
<td>✔️</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arrivals on Red</td>
<td>✔️</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purdue Travel Time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✔️</td>
</tr>
<tr>
<td>Red Light Violations</td>
<td></td>
<td></td>
<td></td>
<td>✔️</td>
<td></td>
</tr>
<tr>
<td>Preemption</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Purdue Split Failure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✔️</td>
</tr>
<tr>
<td>Pedestrian Delay</td>
<td>✔️</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Phase Termination

No Detection*

Phase 4 at 400 E & 800 N, 4/9/2014

- Phase 4 starts constant call
- SPMs evaluated for % max outs
- Alert email sent


- Gap out
- Max out
- Pedestrian activation (shown above phase line)
- Skip
- Force off
Split Monitor
No Detection*

Phase 6

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

Free
Plan 1
Plan 7
Plan 13
Plan 7
Free
47.4 - 85 Percentile Split
34.8 - 85 Percentile Split
38.0 - 85 Percentile Split
33.9 - 85 Percentile Split
34.3 - 85 Percentile Split
29.3 - 85 Percentile Split
33.1 Avg. Split
30.4 Avg. Split
30.5 Avg. Split
31.4 Avg. Split
25.3 Avg. Split
21.1 Avg. Split
4.1% MaxOuts
41.4% Forceoffs
32.5% Forceoffs
73.4% Forceoffs
5.7% Forceoffs
1.5% MaxOuts
94.2% GapOuts
52.6% GapOuts
67.5% GapOuts
26.6% GapOuts
93.4% GapOuts
95.6% GapOuts
1.2% Skips
1.7% Skips
0.0% Skips
0.0% Skips
3.8% Skips
3.0% Skips

Phase Duration

Time of Day

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Purdue Split Failure
Stop Bar Detection
Purdue Coordination Diagram
Set Back Detection
Purdue Coordination Diagram
Set Back Detection
Approach Delay
Set Back Detection

State Street @ 7200 South - SIG#7188
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

Free
9 AD
7305 TD

Plan 7
17 AD
84313 TD

Time (Hour of Day)

Delay Per Hour (Seconds)

Delay Per Vehicle (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
Set Back Detection

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

<table>
<thead>
<tr>
<th>Plan</th>
<th>Arrivals on Red</th>
<th>Percent Arrivals on Red</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>10% AoR</td>
<td>10% RT</td>
</tr>
<tr>
<td>18</td>
<td>28% AoR</td>
<td>28% RT</td>
</tr>
<tr>
<td>19 P</td>
<td>38% AoR</td>
<td>38% RT</td>
</tr>
<tr>
<td>34</td>
<td>44% AoR</td>
<td>44% RT</td>
</tr>
<tr>
<td>38</td>
<td>51% AoR</td>
<td>51% RT</td>
</tr>
<tr>
<td>41</td>
<td>29% AoR</td>
<td>29% RT</td>
</tr>
<tr>
<td>PP</td>
<td>21% AoR</td>
<td>21% RT</td>
</tr>
<tr>
<td>13</td>
<td>12% AoR</td>
<td>12% RT</td>
</tr>
</tbody>
</table>

Volume (Vehicles Per Hour)

Time (Hour of Day)

Percent AoR

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Pedestrian Delay

Ped Push Buttons
Approach Volumes

Stop Bar Detection

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Hour</td>
<td>7/27/2016 4:30:00 PM</td>
</tr>
<tr>
<td>Peak Hour Factor</td>
<td>0.322</td>
</tr>
<tr>
<td>Peak Hour Volume</td>
<td>8108</td>
</tr>
<tr>
<td>Peak Hour Factor</td>
<td>0.98</td>
</tr>
<tr>
<td>Total Volume</td>
<td>25158</td>
</tr>
<tr>
<td>Northbound Peak Hour</td>
<td>7:45 AM - 8:45 AM</td>
</tr>
<tr>
<td>Northbound Peak Hour D Value</td>
<td>0.643</td>
</tr>
<tr>
<td>Northbound Peak Hour K Value</td>
<td>0.312</td>
</tr>
<tr>
<td>Northbound Peak Hour Volume</td>
<td>3564</td>
</tr>
<tr>
<td>Northbound Peak Hour Factor</td>
<td>0.948</td>
</tr>
<tr>
<td>Northbound Total Volume</td>
<td>11440</td>
</tr>
<tr>
<td>Southbound Peak Hour</td>
<td>4:30 PM - 5:30 PM</td>
</tr>
<tr>
<td>Southbound Peak Hour D Value</td>
<td>0.58</td>
</tr>
<tr>
<td>Southbound Peak Hour K Value</td>
<td>0.374</td>
</tr>
<tr>
<td>Southbound Peak Hour Volume</td>
<td>5132</td>
</tr>
<tr>
<td>Southbound Peak Hour Factor</td>
<td>0.96</td>
</tr>
<tr>
<td>Southbound Total Volume</td>
<td>13718</td>
</tr>
</tbody>
</table>
Approach Speed
Set Back Radar Detection

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

- Posted speed
- Use 85th percentile to set yellow & red clearance intervals
Approach Speed

Set Back Radar Detection

Progression speed for snow plans?
Snow storm starts
Turning Movement Counts
Lane by Lane Stop Bar Detection

US-89 Main Street (American Fork) SIG90023
Tuesday, October 22, 2013 12:00 AM - Tuesday, October 22, 2013 11:59 PM

Westbound Thru
TV: 7566 PH: 5.15 PM - 6.14 PM PHV: 721 VPH
PHF: 0.9 PU: 0.96

Southbound Left
TV: 5090 PH: 1.90 PM - 2.02 PM PHV: 533 VPH
PHF: 0.99 PU: 0.87

US-89 Main Street (American Fork) SIG90023
Tuesday, October 22, 2013 12:00 AM - Tuesday, October 22, 2013 11:59 PM

Eastbound Thru
TV: 8076 PH: 5.09 AM - 6.02 AM PHV: 757 VPH
PHF: 0.98 PU: 0.74
Purdue Travel Time
Probe Data

Cumulative Frequency Chart

Bangerter Hwy: SR-201 to 7000 S, Southbound

9.5 miles
1 DDI
7 CFIs
4 8-phase signals

After
Before
Red Light Monitoring
Stop Bar Detection
Offset Optimization Using Link Pivot Algorithm

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

<table>
<thead>
<tr>
<th><a href="mailto:SPMWatchDog@utah.gov">SPMWatchDog@utah.gov</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>5092 - SR-126 (1900 W) &amp; Riverdale (S300 S) (Roy) - Phase: 1</td>
</tr>
<tr>
<td>5105 - Antelope (SR-108/2000 N) &amp; I-15 NB (Layton) - Phase: 4</td>
</tr>
<tr>
<td>6022 - US-89 &amp; Pacific Dr (American Fork) - Phase: 3</td>
</tr>
<tr>
<td>6305 - 400 East &amp; 800 North - Phase: 4</td>
</tr>
<tr>
<td>6310 - Center Street (Orem) &amp; I-15 SPUI - Phase: 8</td>
</tr>
<tr>
<td>7055 - Bangerter Hwy (SR-154) &amp; SR-201 DDI - Phase: 5</td>
</tr>
<tr>
<td>7062 - Bangerter Hwy (SR-154) &amp; 4700 South - Phase: 11</td>
</tr>
<tr>
<td>7613 - 10600 South &amp; 790 West - Phase: 8</td>
</tr>
<tr>
<td>8114 - Bluff Street &amp; I-15 NB Ramps - Phase: 4</td>
</tr>
</tbody>
</table>
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?

Statewide Summary 24 hours / day in Utah for August 2014

<table>
<thead>
<tr>
<th>Month</th>
<th>Arrival on Red</th>
<th>Volume</th>
<th>Intersections</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percent</td>
<td>Platoon Ratio</td>
<td>Daily Average Per Approach</td>
</tr>
<tr>
<td>Aug 2014</td>
<td>30%</td>
<td>1.16</td>
<td>10,740</td>
</tr>
</tbody>
</table>

Regional, corridor and intersection summaries available.
Who is currently using ATSPMs?

• Seminole County FL (300+ signals)  
  http://spm.seminolecountyfl.gov/signalperformancemetrics/

• Utah DOT (1700+ signals)  
  http://udottraffic.utah.gov/atspm/

• City of Las Vegas (280+ signals)  
  http://challenger.nvfast.org/spm/

• AL, FL, GA, IN, MN, OR, PA, VA, WI DOTs

• Pocatello, ID; Tucson, AZ; Richardson, TX; College Station, TX; Tuscaloosa, AL; Overland Park, KS; Salt Lake City (and all regional cities), UT;
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
What can Automated Signal Performance Measures do for you?

- Identify problems more quickly – without waiting for the complaint call
- Troubleshoot complaints and reduce wasted time for maintenance staff
- 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
Engineers can now directly measure what they previously could only estimate and model.
Questions?

Susan Langdon, PE, PTOE
Susan.Langdon@stantec.com
Stantec – Richardson, TX
214.468.8200
High-Resolution Event Data Concept

Signal States → Controller Unit → Internal data logger – 0.1 second resolution → Relational Database → Postgres/SQL Server

Vehicle Detections
Approach Delay
Set Back Detection

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

Average Delay Per Vehicle = 219 Seconds.
Total Delay For Selected Period = 599597 Seconds

Simplified Approach Delay. Displays time between detector 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.
Approach Volumes
Stop Bar and Approach Detection

Metric | Value
--- | ---
Total Volume | 1.640
Peak Hour | 7:45 AM - 8:45 AM
Peak Hour Volume | 685
PHF | 0.948
Peak Hour K-factor | 9.0779
Northbound Total Volume | 1.640
Northbound Peak Hour | 7:45 AM - 8:45 AM
Northbound Peak Hour Volume | 685
Northbound PHF | 0.948
Northbound Peak Hour K-factor | 9.0779
Northbound Peak Hour D-factor | NaN
Southbound Total Volume | 0
Southbound Peak Hour | 1:20 AM - 1:20 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 | 21.26
Peak Hour | 5:00 PM - 6:00 PM
Peak Hour Volume | 2719
PHF | 0.985
Peak Hour K-factor | 6.307
Northbound Total Volume | 18.56
Northbound Peak Hour | 5:00 PM - 6:00 PM
Northbound Peak Hour Volume | 1448
Northbound PHF | 0.894
Northbound Peak Hour K-factor | 0.9002
Northbound Peak Hour D-factor | 0.822
Southbound Total Volume | 12.832
Southbound Peak Hour | 5:15 PM - 6:15 PM
Southbound Peak Hour Volume | 1226
Southbound PHF | 1
Southbound Peak Hour K-factor | 0.973
Southbound Peak Hour D-factor | 1.18