UDOT Automated Traffic Signal Performance Measures (ATSPMs)

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UDOT Statewide Signal Engineer
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Traffic Signals in Utah

1995 Traffic Signals

- Partner Agencies: 40%
- UDOT: 60%

86% Connected

- Partner Agencies: 31%
- UDOT: 55%
Opportunity from UDOT Executive Leaders (2011)

“What would it take for UDOT’s traffic signals to be world class?”

“What’s the trend – are signal operations improving, staying the same or getting worse?”

“What are our areas of most need?”

Quality Improvement Team
QIT Recommendations (July 2011)

• Communications and detection maintained during projects
• Proactive signal maintenance
• Real-time monitoring of system health and quality of operations
PERFORMANCE MEASURES FOR TRAFFIC SIGNAL SYSTEMS

An Outcome-Oriented Approach

SPM Basic Concept

Automated Data Collection
- Signal controller
- Probe source

Useful Information about Performance
- Signal
- Corridor
- System

Why **Model** what you can **Measure**?
Standard Controller Enumerations

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

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

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

http://docs.lib.purdue.edu/jtrpdata/3/
Standard Controller

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

Preemption Events:

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

Follow this and additional works at: http://docs.lib.purdue.edu/jtrpdata

Recommended Citation

Stansel, J. R.; T. Overman; E. Raamot; R. Deer; D. Miller; D. M. Bullock; C. M. Day; T. M. Bonnan; H. Li; A. Hainen; and S. M. Remias. Indiana Traffic Signal Hi Resolution Data Logger Enumerations. Publication , Indiana Department of Transportation and Purdue University, West Lafayette, Indiana, 2012. doi: http://data.datacite.org/10.4231/K4RN335H.
High-resolution Data

0.1-second resolution

<table>
<thead>
<tr>
<th>Timestamp</th>
<th>Event Code</th>
<th>Event Parameter</th>
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<tr>
<td>6/27/2013 1:30:30.4</td>
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</tbody>
</table>
System Requirements

High-resolution Controller

Communications

Server

1) Get .dat Files
2) Translate Files
   .dat → .csv
3) Store in Database

Software

Detection (optional)

Photo courtesy of the Indiana Department of Transportation
System Requirements

Does NOT require Central Traffic Signal Management Software!

1) Get .dat Files
2) Translate Files
   .dat → .csv
3) Store in Database

Server

Software

Detection (optional)

Photo courtesy of the Indiana Department of Transportation
Objective: Vendor Neutrality
Metrics & Detection Requirements
<table>
<thead>
<tr>
<th>Detection</th>
<th>Metric</th>
</tr>
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<tbody>
<tr>
<td>None</td>
<td>Phase Termination Chart</td>
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<tr>
<td></td>
<td>Split Monitor</td>
</tr>
<tr>
<td></td>
<td>Preemption Details</td>
</tr>
<tr>
<td></td>
<td>Pedestrian Delay</td>
</tr>
<tr>
<td>Advanced Count</td>
<td>Purdue Coordination Diagram</td>
</tr>
<tr>
<td></td>
<td>Approach Volume</td>
</tr>
<tr>
<td></td>
<td>Approach Speed (requires detection</td>
</tr>
<tr>
<td></td>
<td>with speed service)</td>
</tr>
<tr>
<td>Lane-by-lane Presence</td>
<td>Purdue Split Failure</td>
</tr>
<tr>
<td>Lane Group Presence</td>
<td></td>
</tr>
<tr>
<td>Lane-by-lane Stop bar Count</td>
<td>Turning Movement Counts</td>
</tr>
</tbody>
</table>
Detection

None

Available Metrics

- Phase Termination Chart
- Split Monitor
- Pedestrian Delay
- Preemption Details
Metric: Phase Termination Chart

- Free coordination
- Coordinated phases
- Time of Day
- Phase Number
- Gap out
- Max out
- Force off
- Pedestrian activation
- Skip
Metric: Split Monitor

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

Phase Duration

Time of Day
Detection

Setback Count Zones

Available Metrics

- Purdue Coordination Diagram
- Approach Volume
- Arrivals on Red
- Approach Delay
Metric: Purdue Coordination Diagram

Vehicles arriving on green
Vehicles arriving on red
Metric: Approach Volume
Detection

Setback Count Zones with speed

Available Metrics

Approach Speed
Metric: Approach Speed

![Graph showing speed trends throughout the day with a decrease starting at the time of a snow storm.](Image)
Detection

- Lane-by-lane Presence
- Lane Group Presence

Available Metrics

- Purdue Split Failure
Metric: Purdue Split Failure

700 East 900 South Signal 7184 Phase: 6 Southbound
Wednesday, April 27, 2016 12:00 AM - Wednesday, April 27, 2016 11:59 PM
Total split fails for the selected period = 93
Detection

Lane-by-lane Count

Available Metrics

Turning Movement Counts
Metric: Turning Movement Counts

Detection Requirements: Stop Bar Counters
System Health with SPMs
## System Health Alerts

<table>
<thead>
<tr>
<th>Alert Type</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>No SPM Data</td>
<td>1</td>
</tr>
<tr>
<td>Too many max outs</td>
<td>2</td>
</tr>
<tr>
<td>Too many force offs</td>
<td>3</td>
</tr>
<tr>
<td>Too many ped calls</td>
<td>4</td>
</tr>
<tr>
<td>Low PCD detector count</td>
<td>5</td>
</tr>
</tbody>
</table>

### SPM Alerts for 5/22/2016

- **No SPM Data**: 1
- **Too many max outs**: 2
- **Too many force offs**: 3
- **Too many ped calls**: 4
- **Low PCD detector count**: 5

---

--The following signals had too few records in the database:
- 4671 - 13400 South & 4500 West - Phase: 0 (Missing Records)
- 5761 - 500 South & 400 East (Bluff) - Phase: 0 (Missing Records)

--The following signals had too many force off occurrences:
- 1224 - North Temple & Main Street - Phase: 2 (Force Offs 97.6%)
- 7252 - 500 South & Main Street - Phase: 2 (Force Offs 100%)
- 7252 - 500 South & Main Street - Phase: 6 (Force Offs 100%)

--The following signals had too many max out occurrences:
- 1123 - Wolcott St & 100 South - Phase: 2 (Max Outs 100%)
- 1124 - Sunnyside (860 S) & Gaurdsman Way - Phase: 2 (Max Outs 100%)
- 1124 - Sunnyside (850 S) & Gaurdsman Way - Phase: 6 (Max Outs 100%)
- 4024 - 7000 South (Fort Union) & 1300 East - Phase: 7 (Max Outs 92.6%)
- 4025 - 1700 South & 700 East - Phase: 1 (Max Outs 100%)
- 4103 - 4690 South (Murray-Holladay) & 2320 East (Holladay) - Phase: 5 (Max Outs 100%)
- 4118 - 6200 South & 3555 West (Dixie) - Phase: 2 (Max Outs 100%)
- 4511 - 4100 South & 3200 West - Phase: 4 (Max Outs 100%)
- 4820 - 4335 South & 2700 West - Phase: 2 (Max Outs 100%)
- 5063 - Lincoln & 24th - Phase: 4 (Max Outs 100%)
- 5063 - Lincoln & 24th - Phase: 6 (Max Outs 100%)
- 5080 - Washington & Adams - Phase: 5 (Max Outs 100%)
- 5170 - 200 N (Kaysville) & Main St. - Phase: 4 (Max Outs 100%)
- 5906 - Main St. & 200 North (Logan) - Phase: 7 (Max Outs 96.2%)
- 5900 - 900 W. (Kays Dr.) & 200 North, (Kaysville) - Phase: 4 (Max Outs 90.4%)
- 6035 - Pioneer Crossing & Millpond Drive - Phase: 8 (Max Outs 91.3%)
- 6608 - 100 West & 100 North - Phase: 8 (Max Outs 98.5%)
- 7107 - Redwood Road & 4700 South - Phase: 5 (Max Outs 93.2%)

--The following signals had unusually low detector hits:
- 5134 - SR-193 (700 S) & I-15 NB (Clearfield) - Phase: 2 (Has Unusually Low Counts.)
- 7061 - Bangerter Hwy (SR-154) & 4100 South - Phase: 1 (Has Unusually Low Counts.)
- 7061 - Bangerter Hwy (SR-154) & 4100 South - Phase: 7 (Has Unusually Low Counts.)
- 7361 - Bangerter Hwy (SR-154) - 13400 South - Phase: 1 (Has Unusually Low Counts.)

--The following signals have stuck ped detectors:
- 1023 - South Temple & 200 West - Phase: 2 (Stuck Ped)
- 1023 - South Temple & 200 West - Phase: 4 (Stuck Ped)
- 1023 - South Temple & 200 West - Phase: 6 (Stuck Ped)
- 1023 - South Temple & 200 West - Phase: 8 (Stuck Ped)
- 4511 - 4100 South & 3200 West - Phase: 4 (Stuck Ped)
- 6099 - Main (Lehi) & I-15 SPUI - Phase: 6 (Stuck Ped)
- 7826 - 9800 S (Little Cottonwood Rd) & Wasatch Blvd (3500 E) - Phase: 4 (Stuck Ped)
Metric: Purdue Phase Termination Detection Requirements: None

2. Too many max outs

Phase 4 starts constant call

SPMs evaluated for % max outs

Alert email sent

4/8/2014

4/9/2014

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

- 0%
- 3%
- 100%
- 5%
- 100%

Metric: Purdue Phase Termination Detection Requirements: None
4. Too many ped calls

Ph6 Ped Constant Call

SPMs evaluated for Ped Activations

Alert email sent

5/21/2016

5/22/2016
# Work Orders for ATMS Equipment

## July 2015 to July 2016

<table>
<thead>
<tr>
<th>Category</th>
<th>Work Orders</th>
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</thead>
<tbody>
<tr>
<td>Traffic Signals</td>
<td>1200</td>
</tr>
<tr>
<td>Detection Problem</td>
<td>400</td>
</tr>
<tr>
<td>Flash</td>
<td>200</td>
</tr>
<tr>
<td>Operations</td>
<td>800</td>
</tr>
<tr>
<td>Damaged/Broken Equipment</td>
<td>600</td>
</tr>
<tr>
<td>No power or comm</td>
<td>400</td>
</tr>
<tr>
<td>Bad Image</td>
<td>200</td>
</tr>
<tr>
<td>No control</td>
<td>1000</td>
</tr>
<tr>
<td>Damaged/Broken Equipment</td>
<td>200</td>
</tr>
<tr>
<td>Sensor Problem</td>
<td>600</td>
</tr>
<tr>
<td>No power or comm</td>
<td>400</td>
</tr>
<tr>
<td>VMS, TMS, &amp; VSL</td>
<td>200</td>
</tr>
<tr>
<td>Detection Problem</td>
<td>1000</td>
</tr>
<tr>
<td>No power or comm</td>
<td>400</td>
</tr>
<tr>
<td>Damaged/Broken Equipment</td>
<td>200</td>
</tr>
<tr>
<td>RWIS</td>
<td>1000</td>
</tr>
<tr>
<td>No power or comm</td>
<td>400</td>
</tr>
<tr>
<td>Cabinet</td>
<td>200</td>
</tr>
<tr>
<td>Detection Problem</td>
<td>1000</td>
</tr>
<tr>
<td>Damaged/Broken Equipment</td>
<td>200</td>
</tr>
<tr>
<td>Ramp Meter</td>
<td>1000</td>
</tr>
</tbody>
</table>

**Note:** The bar chart shows the number of work orders for different equipment categories over the specified period.
Troubleshooting with SPMs
Complaint: Long red at 2 a.m., no other traffic

Before Video detection not working at night

Minor street through & left turn max out at night only

Metric: Purdue Phase Termination Detection Requirements: None
Complaint: Long red at 2 a.m., no other traffic

After New detection technology installed

Phases are rarely used at night

Metric: Purdue Phase Termination
Detection Requirements: None
Signal Optimization with SPMs
Optimization with SPMs

**Traditional Process**

1. Collect Data
2. Model
3. Optimize
4. Implement & Fine-tune

**Modified Process with SPMs**

1. Review SPMs & Field Observation
2. Model
3. Optimize
4. Implement & Fine-tune
5. Time-of-day Cycle Length Splits
6. Offsets
Evaluate Impact of Timing Change

- **Before:**
  
  1 2 | 3 4
  
  5 6 | 7 8

- **After:**
  
  1 2 | 4 3
  
  5 6 | 7 8
Benefits Reporting

2013 Purdue Coordination Diagrams

Initial Percent Arrival on Green
Increase in Percent Arrival on Green
Decrease in Percent Arrival on Green

Corridor Midday Arrival on Green

74%
Monitor Trends

Percent of Vehicles Arriving on Green - Riverdale Rd

10:00 AM to 2:00 PM Monday through Friday

Retiming Project
SPM Use Beyond Signal Operations
Allow Lane Closures

Volume report for University Avenue East Bay Boulevard on the Northbound and Southbound approaches.
7/7/2016 12:00:00 AM - 7/7/2016 11:59:00 PM - Using Advanced Detection

Time (Hour of Day)
Planning Data

Turning movement or Approach counts 24/7/365

Available at 333 signals

28% of State signals!
Active Transportation
http://udottraffic.utah.gov/signalperformanceMetrics
16 Agencies using SPMs

- MnDOT
- Overland Park, KS
- All of Utah
- INDOT
- Seminole County, FL
- WISDOT
- Tuscaloosa, AL
- Tuscon, AZ
- College Station, TX
- Richardson, TX
- PennDOT
- Pocatello, ID
- Las Vegas (FAST)
- VDOT
- INDOT
- VDOT
- FDOT
- GDOT
- ODOT
SPM Source Code -> Open Source
Nov. 2016
Salt Lake SPM Workshop Participants – Jan 2016

170 Representatives from 85 Different Organizations, 28 States, DC, & Canada
Implementation of Automated Traffic Signal Performance Measures

Automated Traffic Signal Performance Measures

Implementation

The software developed by UDOT has been shared freely with multiple agencies and companies around the country. Several cities and DOTs, including a few in Canada, have shown interest in it. Currently, five locations are using SPMs and at least four are in the process of implementing the system.

SIGNAL PERFORMANCE METRICS IN UTAH

To see how SPMs work, visit UDOT’s live website.

SPMs USEAGE/INTEREST MAP

Map of SPMs system usage and interest.
EDC-4 Innovations (2017-2018)

Automated Traffic Signal Performance Measures (ATSPMs)
Highway agencies typically rely on complaints or manual data collection to identify the need for signal retiming projects and their outcomes. These projects are typically scheduled on a 3- to 5-year cycle, at a cost of approximately $4,500 per intersection. The costs and effort associated with collecting performance data translates into congestion, reduced safety, and increased delays for vehicles, pedestrians, and bicyclists.

That's where automated traffic signal performance measures come in. They will revolutionize the management of traffic signals by providing the high-resolution data needed to actively manage performance. High-quality service can be delivered to customers with significant cost savings to agency maintenance and operations. A number of implementation options are available, ranging from a low-cost, open-source code framework to a fully integrated traffic signal system.

Collaborative Hydraulics: Advancing to the Next Generation of Engineering (CHANGE)
Current modeling techniques used for hydraulic design apply several assumptions that can lead to overly conservative or inaccurate results. Advanced hydraulic modeling technologies...
Innovation/Adoption Curve

- Purdue
- INDOT
- MnDOT
- AASHTO
- All
- FHWA
- EDC-4

INITIATORS

2.5%

UDOT

EARLY ADAPTORS

13.5%

EARLY MAJORITY

34%

LATE MAJORITY

34%

LAGGARDS

16%
UDOT Signal Timing Focus Group (July 2014)

- How do you feel about UDOT?
- How do traffic signals make you feel?
Focus Group Key Findings (July 2014)

UDOT is perceived positively, with innovation as the primary driver of positive impressions.

Drivers believe traffic signal synchronization is improving.

Drivers feel UDOT should be open about its accomplishments in a way that protects its credibility.
60s Commercial – Green Lights

http://udot.utah.gov/greenlights
Alert Evaluation

1. No SPM Data
   - Check communication to signal
   - Check controller clock
   - Check IP address in SPM configuration
   - Check VOIT Trace Enabled & Saving-wait
   - Try enabling Upload Current
   - Create a WO to cold start the controller

2. Too many max outs
   - Check for recalls
   - Check for constant call on a detector channel
   - Consider whether a bandaid is necessary

3. Too many force offs
   - Should the signal be in coordination?
   - Is a non-coordinated phase maxing out?
   - Skip only 2-6 pairs and dummy phases

4. Too many ped calls
   - Check for recalls
   - Check for constant call on a detector channel

5. Low PCD detector count
   - Note: Evaluate the VOLUME on the PCD charts, not the phase data
   - Is count channel configured correctly in SPM Config Tool?
   - Is ECPI Log enabled for count channel?
   - Is the detector working?
   - Is the detector communicating to the controller?
   - Try resetting the sensor and VERIFY with Upload Current
Determine Approach Capacity

US-89 Nicholls Rd SIG#5208
Wednesday, May 11, 2016 12:00 AM - Wednesday, May 11, 2016 11:59 PM

Northbound Thru

TV: 16693 PH: 4:45 PM - 5:45 PM PHV: 2505 VPH
PHF: 0.97 fLU: 0.95

Total Volume  Lane 1  Lane 2
“Can we oversize the peds?”

Peds for Phases 4 & 8 are called **frequently**
Recommendation: Do not oversize peds

Peds for Phases 4 & 8 are **rarely** called
Recommendation: Oversize peds, if needed

**Gap out**
**Max out**
**Force off**

**Pedestrian activation**
(shown above phase line)

**Skip**

**Metric:** Purdue Phase Termination Detection Requirements: None
“Can we oversize the peds?”

Peds for Phases 4 & 8 are called **frequently**
Recommendation: Do not oversize peds

Peds for Phases 4 & 8 are **rarely** called
Recommendation: Oversize peds, if needed

Pedestrian Delay:

Metric: Purdue Phase Termination Detection Requirements: None