Quest for World-Class Traffic Signals

Northern California Section – ITE
June 15, 2016

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Utah Department of Transportation
Agenda

• About UDOT & UDOT Traffic Operations Center

• Innovative ideas
  • Reflectorized backplates
  • Custom controller logic
  • Generator plug transfer switch; Key switch for crossing guards

• Vehicle Detection – UDOT’s use of Wavetronix radar

• Automated Traffic Signal Performance Metrics (SPMs)
  • How they work, how to get them, case studies
  • Impacts on operations in Utah
UDOT Traffic Operations Center
TOC Control Room Operators (24/7 coverage)
Variable Message Signs
(96 Freeway, 49 surface street)
Monday Safety Message

GET YOUR HEAD OUT OF YOUR APPS
CCTV Cameras
(1125 statewide – Shared by all Agencies)
Remote Weather Information Systems
(97 devices statewide)
In-House Meteorologists
Accurate **Road Weather** Forecasts help with Mobility and Safety
Traffic Signal Desk Coverage – 12 hours/day
Special Event, 29%
Field Timing Downloads, 25%
Congestion Responses, 20%
Crash Responses, 13%
Construction, 9%
Other, 4%
UDOT Signal Desk Activity
2003 to 2016
Special Event Plans Enabled

*As of 5/25/2016
Traffic Signals in Utah

1995 Traffic Signals

- Partner Agencies: 41%
- UDOT: 59%

84% Connected

- Partner Agencies: 31%
- UDOT: 53%
Reflectorized Tape – Proven Safety Countermeasure

- 15% reduction in all crashes at urban, signalized intersections.
  - Source: Insurance Corporation of British Columbia & Canadian National Committee on Uniform Traffic Control
- Big advantage during power outages when signal is dark.
- UDOT policy to provide 2 inch tape.
Reflectorized Backplate Tape
Generator Plugs on Signal Cabinets

- Signal electricians are few in number and centralized at region headquarters
- Leverage existing resources at maintenance sheds scattered throughout Utah
  - Equip sheds with generators (3 per shed)
  - Shed personnel assist with blackouts
  - Much faster response time
  - Better use of resources
    - i.e. don’t need battery backup systems everywhere
Custom Signal Controller Logic
Custom Logic in Signal Controllers

Custom programming in Signal Controller not possible with built in parameters

- Transit Priority
- Innovative Intersections (CFI, DDI, SPUI, Etc.)
- Railroad preemption
- Flex Lanes
- Advanced Warning Systems
- Delayed-Start of Flashing Yellow Arrow

IF...THEN...ELSE...AND...OR
Example Problem: 11400 S & 3200 W

- New intersection built with Protected Left for Westbound and FYA for Eastbound.
- Protected left generated red light violation problems and numerous delay complaints.
Example Problem: 11400 S & 3200 W

- If there is a car in the EB-to-NB left turn lane, it may be hard for a driver in WB-to-SB left turn lane to see EB traffic.
Example Problem: 11400 S & 3200 W

• View from perspective of WB-to-SB left turn lane
Example Problem: 11400 S & 3200 W

- Westbound was changed from a protected left to a FYA.
- Logic used to delay or omit the FYA if a vehicle is in the opposite left turn lane.
Key Switch

Activating the switch with a key will enable Walk 2 for Phases 4 & 8.
Mounting

Key switch installed with weather proof cover plate
Key Switch

With the key in Switch – Key doesn’t come out when turned on.
Operation

- When key switch is on, WALK goes from 5 s to 15 s and PED CLEAR stays the same.

Training Crossing Guard
Detection Technologies Used

- Some Inductive Loops – wired in series & grouped by Lane Groups

- Some Video – Traficon, AutoScope, Iteris, Gridsmart

- Some Sensys Networks Magnetometers

- Mostly Wavetronix Radar
  - Advance: 715 intersections & 1470 approaches
  - Matrix: 783 intersections & 2196 approaches
Advanced Detection – Arterials Ch. 1
(Installed at speeds 40 mph+)

1.0 S Passage time is used in controller

If stop bar detection is present, queue clearance is not used.

Large Trucks – DZ

Small Trucks/Vehicles - DZ

Queue Clearance of Waiting Vehicles
Channel 2 used for approach volume counts with a 10 foot zone approximately 400 feet from the stopbar.
UDOT Detection Setup StopBar
(Sidestreet & Most MainLine)

Wavetronix Matrix Smartsensor Radar

Queue Ch.: 15 ft Long @ 50’ Back
- 3 second delay

- Count ch. at Stopbar
  - Ex. Ch. 5–8 (underneath)

- YRA ch. at stopbar
  - Yellow & Red Actuations
  - Ex. Ch. 9-11.
  - 15 mph speed filter
Depending on the sensor positioning, layout, and available channels, sometimes we use exit counting channels.
The larger the detection zone, the smaller the passage time (PT). Smaller PT reduces vehicle delay for waiting vehicles on other phases.
Table 5-10 Passage time duration for presence mode detection

<table>
<thead>
<tr>
<th>Maximum Allowable Headway, s</th>
<th>Detection Zone Length, ft</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
<th>45</th>
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<td>25</td>
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<td>1.3</td>
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<tr>
<td>45</td>
<td>1.0</td>
<td>1.3</td>
<td>1.6</td>
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<td>55</td>
<td>0.7</td>
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<td>1.3</td>
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<td>1.7</td>
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<td>0.4</td>
<td>0.8</td>
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<td>75</td>
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<td>0.6</td>
<td>0.9</td>
<td>1.2</td>
<td>1.4</td>
<td></td>
</tr>
</tbody>
</table>

25 mph: 2.2 - .4 = 1.8 s.  
30 mph: 2.3 - .8 = 1.5 s.  
35 mph: 2.4 - 1.1 = 1.3 s.  
40 mph: 2.5 - 1.4 = 1.1 s.  
45 mph: 2.6 - 1.5 = 1.1 s.  

Ave: 1.4 S savings with 65 foot zone.
## Detector Channel Map

<table>
<thead>
<tr>
<th>Detector Channel</th>
<th>Phase</th>
<th>Description</th>
<th>Logic ID</th>
<th>Sensor Channel</th>
<th>Add</th>
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<tbody>
<tr>
<td>17</td>
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<td>22</td>
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<td>WB Thru Lane 1 Exit Count</td>
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<tr>
<td>26</td>
<td></td>
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<td>32</td>
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<td>NB Thru 2 Count</td>
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</table>

## Detector Channel Map

<table>
<thead>
<tr>
<th>Detector Channel</th>
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<th>Description</th>
<th>Logic ID</th>
<th>Sensor Channel</th>
<th>Add</th>
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<tbody>
<tr>
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<tr>
<td>Number of Approach Lanes</td>
<td>Volume Level</td>
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<td></td>
<td></td>
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<tr>
<td>-------------------------</td>
<td>----------------------</td>
<td>----------------</td>
<td>----------------</td>
<td>----------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low (%) (≤100 v/h/ln)</td>
<td>Mid (%) (101-250 v/h/ln)</td>
<td>High (%) (&gt;250 v/h/ln)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower</td>
<td>Upper</td>
<td>Lower</td>
<td>Upper</td>
<td>Lower</td>
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<td>94.6</td>
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<td>97.4</td>
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<tr>
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<td>100.1</td>
<td>91.7</td>
<td>100.1</td>
<td>90.8</td>
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<tr>
<td>5</td>
<td>91.9</td>
<td>97.2</td>
<td>88.8</td>
<td>96.3</td>
<td>80.3</td>
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<td>93.8</td>
<td>96.8</td>
<td>79.7</td>
<td>88.6</td>
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</table>
### Radar Wavetronix Advance - Volume Accuracy – Report No. UT-16.05 Table 5-4. – Combined 95% Confidence Interval of the Mean

<table>
<thead>
<tr>
<th>Number of Approach Lanes</th>
<th>Volume Level</th>
<th>Low (%) (≤100 v/h/ln)</th>
<th>Mid (%) (101-250 v/h/ln)</th>
<th>High (%) (&gt;250 v/h/ln)</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Lower</td>
<td>Upper</td>
<td>Lower</td>
</tr>
<tr>
<td>1</td>
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<td>94.7</td>
<td>116.7</td>
<td>98.1</td>
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<td>87.6</td>
<td>104.0</td>
<td>86.9</td>
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<tr>
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<td></td>
<td>85.7</td>
<td>94.9</td>
<td>80.6</td>
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</table>

**Speed Accuracy**
Learning Hub

TITLE: Achieve Your Agency's Measures

DATE: Wednesday, April 9, 2014

TIME: 12:00 p.m. - 1:30 p.m. Eastern Time

ITA 3-part Webinar
April, May, June 2014

ITE Journal, March 2014

Helping Traffic Engineers Manage Data to Make Better Decisions

Automated Traffic Signal Performance Measures

By Darcy Bullock, P.E., Rob Clayton, P.E., PTOE, Jamie Mackey, P.E., Steve Misgen, P.E., PTOE, Amanda Stevens, P.E., Jim Sturdevant, P.E., and Mark Taylor, P.E., PTOE

Improved signal operations with smooth and equitable traffic flow are goals for most traffic engineers; however, the limited snapshot-view retiming methods that involve manual data collection, traffic signal modeling, and field fine-tuning are resource-intensive and unresponsive to changes in traffic patterns. The National Transportation Operations Coalition’s 2012 National Traffic Signal Report Card has led agencies to focus resources on these activities and develop methodologies to examine all the components of traffic signal operations. These data-driven program management plans provide objective methods for identifying shortcomings and encourages coordination with neighboring jurisdictions. In addition, agencies need tools to prioritize activities when resources are constrained.
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

http://udottraffic.utah.gov/signalperformance.metrics
Agencies using UDOT SPMs

- Pocatello, ID
- All of Utah
- Las Vegas
- Tuscon, AZ
- College Station, TX
- Richardson, TX
- Overland Park, KS
- Seminole Cty, FL
- College Station, TX
- Tuscon, AZ
- Overland Park, KS
- MnDOT
- INDOT
- VDOT
- GDOT
- FDOT
- PennDOT
- WISDOT
- MnDOT
- All of Utah
SPM Basic Concept

Automated Data Collection
- Signal controller
- Probe source

Useful Information about Performance
- Signal
- Corridor
- System

Why Model what you can Measure?

A Central Signal System is NOT used or Needed for these SPM’s.
System Requirements

High-resolution Controller

Communications

Server

Software

Detection (optional)

Photo courtesy of the Indiana Department of Transportation
Objective: Vendor Neutrality
Metrics & Detection Requirements

<table>
<thead>
<tr>
<th>Controller high-resolution data only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purdue Phase Termination</td>
</tr>
<tr>
<td>Split Monitor</td>
</tr>
<tr>
<td>Pedestrian Delay (Ped Buttons)</td>
</tr>
</tbody>
</table>
Phase Termination Chart

Detection Requirements: None
Nighttime detection problem

BEFORE: Video detection not working at night

Minor street through & left turn max out at night only

Metric: Purdue Phase Termination
Detection Requirements: None
Nighttime detection problem – Fixed!

► AFTER: New detection technology installed

Phases are rarely used at night

**Metric:** Purdue Phase Termination Detection Requirements: None

- Gap out
- Pedestrian activation (shown above phase line)
- Max out
- Skip
- Force off
Alert Example: 100% Max Out

- Daily email at 7 a.m.
- Uses Purdue Phase Termination chart data
- Flags phases with >90% max-outs on each phase between 1 a.m. and 5 a.m. after 20 occurrences
- Compare to previous day’s list. Only phases with new flags are sent in the email.

Example:

```
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 (Salt Lake City) - Phase: 4
6022 - US-89 & Pacific Dr (American Fork) - Phase: 3
6305 - 400 East & 800 North - Phase: 4
6310 - Center Street (Orem) & I-15 SPUI - Phase: 8
7055 - Bangerters Hwy (SR-154) & SR-201 DDI - Phase: 5
7062 - Bangerters Hwy (SR-154) & 4700 South - Phase: 11
7613 - 10600 South & 700 West - Phase: 8
8114 - Bluff Street & I-15 NB Ramps - Phase: 4
```

Metric: Purdue Phase Termination
Detection Requirements: None
Split Monitor

Phase 6

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

<table>
<thead>
<tr>
<th>Metric</th>
<th>Plan 1</th>
<th>Plan 7</th>
<th>Plan 13</th>
<th>Plan 7</th>
<th>Free</th>
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</thead>
<tbody>
<tr>
<td>94.2% GapOuts</td>
<td>52.6% GapOuts</td>
<td>67.5% GapOuts</td>
<td>26.6% GapOuts</td>
<td>90.6% GapOuts</td>
<td>95.6% GapOuts</td>
</tr>
<tr>
<td>4.1% MaxOuts</td>
<td>41.4% ForceOffs</td>
<td>32.5% ForceOffs</td>
<td>73.4% ForceOffs</td>
<td>5.7% ForceOffs</td>
<td>1.5% MaxOuts</td>
</tr>
<tr>
<td>1.2% Skips</td>
<td>1.7% Skips</td>
<td>0.0% Skips</td>
<td>0.0% Skips</td>
<td>3.8% Skips</td>
<td>3.0% Skips</td>
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<tr>
<td>47.4 - 85 Percentile Split</td>
<td>34.8 - 85 Percentile Split</td>
<td>38.0 - 85 Percentile Split</td>
<td>33.9 - 85 Percentile Split</td>
<td>34.3 - 85 Percentile Split</td>
<td>29.3 - 85 Percentile Split</td>
</tr>
</tbody>
</table>

Metric: Split Monitor
Detection Requirements: None
Impact of Sequence change w/ Split Monitor

• Before:
  
  1 2 | 3 4
  
  5 6 | 7 8

• After:
  
  1 2 | 4 3
  
  5 6 | 7 8
Pedestrian Delay
(Time from pedestrian call received to start of the walk indication)

Metric: Pedestrian Delay
Detection Requirements: Ped Buttons

Pedestrian Delay
Harrison 26th Signal 5049
Friday, April 22, 2016 12:00 AM - Friday, April 22, 2016 11:59 PM
Phase 4

36 - Ped Acutations (PA) 00:00 - Min Delay 00:56 - Max Delay 00:21 - Average Delay (AD)

36 - Ped Acutations (PA) 00:00 - Min Delay 00:56 - Max Delay 00:21 - Average Delay (AD)
## Metrics & Detection Requirements

**Controller high-resolution data only**
- Purdue Phase Termination
- Split Monitor
- Pedestrian Delay (ped buttons)

**Advanced Count Detection (~400 ft behind stop bar)**
- Purdue Coordination Diagram
- Approach Volume
- Platoon Ratio
- Arrivals on Red
- Approach Delay
- Executive Summary Reports
Progression Quality

Vehicles arriving on green
Vehicles arriving on red
Purdue Coordination Diagram
Bangerter & 5400 S (3/7/2013)

Left turns from upstream signal

Metric: Purdue Coordination Diagram
Detection Requirements: Advance Counters
PCD – TOD Coordination
Mountain View & 12600 S - Westbound

Metric: Purdue Coordination Diagram
Detection Requirements: Advance Counters
PCD – Peer to Peer Logic
Mountain View & 12600 S - Westbound

Metric: Purdue Coordination Diagram
Detection Requirements: Advance Counters
Offset Optimization using Purdue Link Pivot

SR-36

- Village Blvd
- Bates Canyon Rd
- Erda Way
- 2400 N
- 2000 N
### Offset Adjustments

<table>
<thead>
<tr>
<th>Signal</th>
<th>Location</th>
<th>Delta</th>
<th>Adjustment (+/- offset)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7371</td>
<td>Foothill Drive Thunderbird</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>7223</td>
<td>Foothill Drive 2100 South</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td>7222</td>
<td>Foothill Drive 1700 South</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>7221</td>
<td>Foothill Drive 2300 East</td>
<td>110</td>
<td>10</td>
</tr>
<tr>
<td>7220</td>
<td>Foothill Drive 1300 South</td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td>7503</td>
<td>Foothill Drive 2100 East</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>7219</td>
<td>Foothill Drive Sunnyside</td>
<td>110</td>
<td>105</td>
</tr>
<tr>
<td>7218</td>
<td>Foothill Drive Wakara Way (660 S.)</td>
<td>115</td>
<td>115</td>
</tr>
<tr>
<td>7217</td>
<td>Foothill Drive Mario Capecchi Dr (1950 E.)</td>
<td>0</td>
<td>0</td>
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<td></td>
<td>Avg: 42.0</td>
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</table>

### Approach Links (Select a link to view PCDs below)

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<thead>
<tr>
<th>Upstream Signal Id</th>
<th>Upstream Direction</th>
<th>Downstream Signal Id</th>
<th>Downstream Direction</th>
<th>% AOG Upstream Existing</th>
<th>% AOG Existing</th>
<th>% AOG Predicted</th>
<th>% AOG Downstream Predicted</th>
<th>AOG Upstream Existing</th>
<th>AOG Existing</th>
<th>AOG Predicted</th>
<th>AOG Downstream Predicted</th>
<th>Delta</th>
<th>Results Graph</th>
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<tr>
<td>7371</td>
<td>Southbound</td>
<td>7223</td>
<td>Northbound</td>
<td>96</td>
<td>96</td>
<td>84</td>
<td>85</td>
<td>1755</td>
<td>1756</td>
<td>1211</td>
<td>1215</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>7223</td>
<td>Southbound</td>
<td>7222</td>
<td>Northbound</td>
<td>87</td>
<td>87</td>
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<td>92</td>
<td>1421</td>
<td>1421</td>
<td>2451</td>
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</table>
Metrics & Detection Requirements

Controller high-resolution data only

- Purdue Phase Termination
- Split Monitor
- Pedestrian Delay (Ped Buttons)

Advanced Count Detection (~400 ft behind stop bar)

- Purdue Coordination Diagram
- Approach Volume
- Platoon Ratio
- Arrivals on Red
- Approach Delay
- Executive Summary Reports

Advanced Detection with Speed

- Approach Speed
Approach Speeds
Use for traffic studies, models, setting speed limits, Yellows, Red Clearance

43% of Intersections

**Metric: Approach Speeds**
Detection Requirements: Wavetronix Advance Radar
Approach Speeds and Snow

Snow storm starts

Progression speed for snow plans?

Metric: Approach Speeds
Detection Requirements: Wavetronix Advance Radar
# Metrics & Detection Requirements

## Controller high-resolution data only
- Purdue Phase Termination
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- Pedestrian Delay (ped buttons)

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## Advanced Detection with Speed
- Approach Speed

## Lane-by-lane Presence Detection
- Purdue Split Failure
Purdue Split Failure – 24-hr Format

Phase 4 EBT Coordinated Phase

Metric: Purdue Split Failure
Detection Requirements: Stop bar presence
Moab, Utah – The Adventure Capital of the United States
(Two National Parks within 20 miles)
Purdue Split Failure — NB Center St & Main St – Moab, Utah (Memorial Day Weekend – Saturday)

Metric: Purdue Split Failure
Detection Requirements: Stop bar presence

2015

2016
Purdue Split Failure — SB Center St & Main St – Moab, Utah
(Memorial Day Weekend – Saturday)

Metric: Purdue Split Failure
Detection Requirements: Stop bar presence

2015

2016
### Metrics & Detection

#### Requirements

- **Controller high-resolution data only**
  - Purdue Phase Termination
  - Split Monitor
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  - Purdue Coordination Diagram
  - Approach Volume
  - Platoon Ratio
  - Arrivals on Red
  - Approach Delay
  - Executive Summary Reports

- **Advanced Detection with Speed**
  - Approach Speed

- **Lane-by-lane Presence Detection**
  - Purdue Split Failure

- **Lane-by-lane Count Detection**
  - Turning Movement Counts
Lane-by-lane Volume Counts

US-89 Main Street (American Fork) SIG#5023
Tuesday, October 22, 2013 12:00 AM - Tuesday, October 22, 2013 11:59 PM

**Westbound Thru**
TV: 7666 PH: 6:15 PM - 6:15 PM PHV: 721 VPH
PHF: 0.9  I/U: 0.96

**Southbound Left**
TV: 5590 PH: 1:00 PM - 2:00 PM PHV: 533 VPH
PHF: 0.89  I/U: 0.87

**Eastbound Thru**
TV: 8076 PH: 5:00 PM - 6:00 PM PHV: 757 VPH
PHF: 0.95  I/U: 0.74

**Metric: Turning Movement Counts**
Detection Requirements: Stop Bar Counters
Impact of SPMs on Signal Operations in Utah
Performance Metrics Uses

- **Daily Operations**
  - Basic parameters
  - Detection problems
  - Complaint response/troubleshooting
  - Coordination
  - Events, Incidents, Weather, & Construction
  - Alerts

- **Modeling/planning**
  - Approach Volumes
  - Turning Movement Counts
  - Speed

- **Reporting**
  - Prioritize signal needs
  - Communicate system status to region/senior leaders and public
Optimization with SPMs

**Traditional Process**

1. Collect Data
2. Model
3. Optimize
4. Implement & Fine-tune
5. Time-of-day
6. Cycle Length Splits Offsets

**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
Monitoring Trends

Percent of Vehicles Arriving on Green - Riverdale Rd
10:00 AM to 2:00 PM Monday through Friday

Retiming Project
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.
60 S Commercial – Green Lights