Automated Traffic Signal Performance Measures

Penn State Transportation Engineering & Safety Conference
December 6, 2018
Acceptable signal operation?
"The way we've always done it"
Is this better?
Traditional: Model a lot... Measure a little

All of our metrics are based on **outputs** not Objectives

Source: INDOT/FHWA
Is this better?

Data Collection

Modeling
A Better Way

**Traditional Process (Reactive)**

- Trigger
- Collect Data
- Model & Optimize
- Implement & Fine Tune

Complaints
Developer Impact

**Outputs:**
Cycle Length
Splits
Offsets

**Modified Process with Performance Data (Proactive)**

- Review Metrics
- Field Observation
- Model
- Optimize
- Implement & Fine Tune

How do measures compare to agency goals?

**Output:**
Offsets

Adapted from UDOT
Using Data to Measure Arterial Performance

Corridor Level

- Probe speed data
- RITIS/PDA Suite

Intersection Level

- High resolution data
- UDOT ATSPM software
Corridor Level Metrics

Phase 1: Proof of Concept
Phase 2: Enabling Access, Scalability, and Usability
Probe Data

- Pennsylvania INRIX coverage
  - 25,000 TMC segments = 16,600 miles
  - 112,000 XD segments = 23,200 miles (20,200 on arterials)
Research / Proof of Concept

- **TRB Annual Meeting 2017 Paper # 17-00314**
  - [http://docs.trb.org/prp/17-00314.pdf](http://docs.trb.org/prp/17-00314.pdf)
- **Proof of Concept**
  - 138 “Super-Critical” corridors in Philadelphia area
  - Covered 2,184 signals on 766 miles of arterials
Travel Time Comparison

- Travel Time
- Reliability

Retiming Week

Before and After Improvement

Improved Travel Time
Improved Reliability
Travel Time Normalization

- Normalize corridors of difference length and speed limits
- Identify corridors with below average performance

![Graph showing travel time normalization]

- Normalize travel times
- Median TT
- Speed Limit TT
Travel Time Normalization
Interquartile-Range (IQR) Normalization

Normalized IQR = \[
\frac{(75\text{th percentile TT} - 25\text{th percentile TT})}{\text{Speed limit TT}}
\]
Travel Time Delta Ranking

Travel Time Normalization Ranking

Interquartile-Range (IQR) Normalization Ranking

Reliability vs Central Tendency
PDA Suite: Corridor and Time Selection

Travel Time Comparison
Travel time comparison allows you to compare a road's travel times against two different time ranges to not an upgrade or downgrade in performance.

1. Select a road

   - Roads List of XD codes Saved XD sets
   - XDs from... Search in Pennsylvania

Your selected road

   - US 30
   - Directions:
     - Eastbound
     - Westbound
     - Entire road
     - Partial road
     - 85 miles of roadway selected (52 XD segments)

   - Report a problem with this road

2. Create one or more time periods

   - Day(s) Month(s) Year(s)

   - 09/11/2017 - through - 09/15/2017

   Limit to specific days of the week:
   - Sun Mon Tue Wed Thu Fri Sat

   - Your selected time periods
   - Remove all

   - 09/21/2017 though 09/25/2017

3. Choose one to three time ranges to analyze within each time period

   - Use default Peak Hours
   - Use custom hours
PDA Suite: Travel Time Comparison

US 30 - Lancaster Ave

Before: 09/21/2017 - 09/25/2017
After: 03/11/2017 - 09/15/2017

**EASTBOUND**
0 AM - 9 AM

Delta: 3 min 30 sec
Faster
- 09/21/2017 - 09/25/2017
  S M T W T F S
  69 min of readings at 47%
- 03/11/2017 - 09/15/2017
  S M T W T F S
  68 min of readings at 47%

**WESTBOUND**
0 AM - 9 AM

Delta: 2 min 56 sec
Faster
- 09/21/2017 - 09/25/2017
  S M T W T F S
  69 min of readings at 47%
- 09/11/2017 - 09/15/2017
  S M T W T F S
  67 min of readings at 47%

Delta: 4 min 1 sec
Slower
- 09/21/2017 - 09/25/2017
  S M T W T F S
  62 min of readings at 47%
- 09/11/2017 - 09/15/2017
  S M T W T F S
  66 min of readings at 47%
PDA Suite: Cumulative Distribution Chart

Travel Time Comparison

US 30 - Lancaster Ave

--- Speed Limit Travel Time

Before

08/21/2017 - 08/25/2017 SMTWTF

After

09/11/2017 - 09/15/2017 SMTWTF

Cumulative Distribution Charts

EASTBOUND
6 AM - 9 AM

36.8 min

100%

75%

50%

25%

0%

Percent of readings

Travel Time (min)

Delta: 3 min 30 sec Faster

08/21/2017 - 08/25/2017 SMTWTF
69 min of readings at 47%

09/11/2017 - 09/15/2017 SMTWTF
66 min of readings at 47%

WESTBOUND
6 AM - 9 AM

37.2 min

100%

75%

50%

25%

0%

Percent of readings

Travel Time (min)
PDA Suite: Change Between Dates

Mixed results for median travel along the corridor

Significant improvements to fastest travel times on the corridor
Central portion of corridor got worse in westbound direction
PDA Suite: Travel Time Delta Ranking
Median and IQR both got **worse**

Median and IQR both got **better**
Intersection-Level Metrics
High Res Data: A Fitness Tracker for Traffic Signals

High Resolution Data Collection

Data Analysis & Performance Reporting

Source: FHWA
ATSPM Implementation

Controller

Detection

Communication
Implementing ATSPM: Controllers

• Buy a new controller for about the same price as doing one round of count, analyze & retime
• Vendor neutral
  – Bulletin 15 #'s in bold below
  – Links to manufacturer product sheets below

**Econolite Cobalt:** Any version **ECO-127P, 128P & 129P**
Econolite ASC3 NEMA: v2.50+ & OS 1.14.03+ **ECO-116P**
Econolite 2070 w/ 1C CPU: v 32.50+

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**Peek ATC:** Greenwave 03.05.0528+ **PTS-042P**

**Trafficware Model 980ATC:** v 76.10+ **TFW-011P**
**Trafficware ATC Controller:** v 76.10+

**Intelight:** Maxtime v1.7.0+ **INT-009P, 010P & 011P**

**McCain ATC Omni eX 1.6+** **MCC-018P**

**Siemens M50 Linux**
**Siemens M60 ATC** **SMS-231P**
ECOM v 3.52+
NTCIP v 4.53+
## Implementing ATSPM: Detection

<table>
<thead>
<tr>
<th>Detection</th>
<th>Metric</th>
</tr>
</thead>
<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>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>
<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 with speed service)</td>
</tr>
</tbody>
</table>
Implementing ATSPM: Communication

Strike-off Letter (SOL) 494-16-02
(Effective: February 12, 2016)

Note: VPN access to PennDOT Network will be used to access signal(s). Internet accessibility is required and will be the responsibility of the signal owner. See “VPN Authorization Process” for further details.
Implementing ATSPM: No Communication

**Equipment** | **Price**
--- | ---
Raspberry Pi 2, Model B | $35
Raspberry Pi Case | $10
Power supply (5V, 1A) | $6
USB to Micro USB (Power Cable) | $4
MicroSD card (16GB) | $10
Ethernet Cable | $2
HDMI Video Cable | $8
GPS Module (GlobalSat BU-353-S4) | $30
Ethernet Switch – *optional* | $25
**Total** | **$130**
ATSPM: Improve progression on critical corridors

• Purdue Coordination Diagram

%AoG > % GT

Few arrivals on red
ATSPM: Split Failures

• **Green Occupancy Ratio (GOR)**
  – % of time detection zone occupied while signal is *green* for the lane(s) served by the phase

• **Red Occupancy Ratio (ROR)**
  – % of time detection zone occupied during *first 5 seconds of red* for the lane(s) served by the phase

• **Split Failure**
  80%+ **GOR**
  AND
  80%+ **ROR**

Termination Type

- GOR - GapOut
- GOR - ForceOff
- ROR - GapOut
- ROR - ForceOff

- SplitFail
- Avg. GOR
- Avg. ROR
- Percent Fails
ATSPM: Minimize delay for intersecting users

Split failures higher mid-morning and early afternoon than during lunch hour
Minimize delay for intersecting users

- **8 sec. programmed split in Plan 2!**
  - (3 second green)
Minimize delay for intersecting users

Consider starting Plan 4 earlier than 7:15 instead of running free?
ATSPM: Minimize delay for intersecting users

Ped recall = broken button

254 second cycle = 4 minutes of ped delay!
ATSPM: Maintain equipment

209 second split? 254 second cycle? Programming error!
ATSPM: Maintain equipment

<table>
<thead>
<tr>
<th>Time</th>
<th>Free</th>
<th>Plan 1</th>
<th>Free</th>
<th>Plan 2</th>
<th>Free</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>16.8s - 85% tile Split</td>
<td>35.0s - 85% tile Split</td>
<td>59.0s - 85% tile Split</td>
<td>40.0s - 85% tile Split</td>
<td>59.0s - 85% tile Split</td>
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<tr>
<td></td>
<td>15.1s Avg. Split</td>
<td>27.8s Avg. Split</td>
<td>59.0s Avg. Split</td>
<td>39.9s Avg. Split</td>
<td>59.0s Avg. Split</td>
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<tr>
<td></td>
<td>0.0% MaxOuts</td>
<td>59.0% ForceOffs</td>
<td>100.0% MaxOuts</td>
<td>100.0% ForceOffs</td>
<td>97.8% MaxOuts</td>
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<tr>
<td></td>
<td>100.0% GapOuts</td>
<td>41.0% GapOuts</td>
<td>0.0% GapOuts</td>
<td>0.0% GapOuts</td>
<td>0.0% GapOuts</td>
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<tr>
<td></td>
<td>0.0% Skips</td>
<td>0.0% Skips</td>
<td>0.0% Skips</td>
<td>0.0% Skips</td>
<td>1.4% Skips</td>
</tr>
</tbody>
</table>

52 sec max. per permit

Utility contractor hit loop

5/21/2018

Time of Day

Termination Type
- Force Off
- Max Out
- Gap Out
- PedActivity
- Unknown
- Programmed Split
ATSPM: Maintain equipment

Same phase before loop cut
ATSPM: Maintain equipment

Revised permit to reduce max time to 26 seconds

Min recall to get cars to loop past stop bar that was still working
ATSPM: Example (Shippensburg, PA)

WB Left: Few split failures

Low green occupancy
ATSPM: Example (Shippensburg, PA)

EB Thru: Split failures < 25%
EB Left: More split failures
Automated Traffic Signal Performance Measures

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