AUTOMATED TRAFFIC SIGNAL PERFORMANCE MEASURES: CASE STUDIES

INSTITUTE OF TRANSPORTATION ENGINEERS WEBINAR PART 2 – MAY 7, 2014
ITE Webinar Series on Automated Traffic Signal Performance Measures (SPMs)

- Achieve Your Agency’s Objectives Using SPMs
  April 9, 2014, 12:00 pm to 1:30 pm. Eastern

- SPM Case Studies
  May 7, 2014, 12:00 pm to 1:30 pm. Eastern

- Critical Infrastructure Elements for SPMs
  June 11, 2014, 12:00 pm to 1:30 pm. Eastern
Automated Traffic Signal Performance Measures

Technology Implementation Group: 2013 Focus Technology

http://tig.transportation.org

Mission: Investing time and money to accelerate technology adoption by agencies nationwide
Your Speakers Today

Jamie Mackey, UDOT
Amanda Stevens, INDOT
Alex Hainen, Purdue

Steve Misgen, MnDOT
Mark Taylor, UDOT

Moderator
AUTOMATED TRAFFIC SIGNAL PERFORMANCE MEASURES
CASE STUDIES: UDOT

INSTITUTE OF TRANSPORTATION ENGINEERS WEBINAR PART 1 – MAY 7, 2014
PRESENTED BY JAMIE MACKEY, UDOT
What Can Automated Traffic Signal Performance Measures Do for You?

- Troubleshoot complaints and reduce wasted time for maintenance staff
- Catch problems as they happen
- Operate & optimize system without field data collection
- Retime signals as needed, not on a schedule
- Communicate signal/corridor/system performance to public & agency leaders
Signal Performance Metrics

Selected Signal
7376 5600 West SR-201 Westbound

Signals
Region: All
Metric Type: All
Filter: Signal ID

Signal List

Map

Metric Settings
Metric Type
- Approach Delay
- Approach Volume
- Arrivals On Red
- Purdue Coordination Diagram
- Purdue Phase Termination
- Speed
- Split Monitor

Y Axis Maximum
Percentile Split: 85

Dates
Start Date: 5/1/2014
End Date: 5/1/2014

Create Metrics

http://udottraffic.utah.gov/signalperformance.metrics
Agencies using UDOT software for SPMs
System Requirements

High-resolution Controller

Communications

Can be done independent of a Central System!

3) Store in Database

Website

Detection (optional)

Photo courtesy of the Indiana Department of Transportation
Metrics & Detection Requirements

Controller high-resolution data only
  - Purdue Phase Termination
  - Split Monitor

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

Lane-by-lane Count Detection
  - Turning Movement Counts

Lane-by-lane Presence Detection
  - Split Failure (future)

Probe Travel Time Data (GPS or Bluetooth)
  - Purdue Travel Time Diagram
UDOT Case Studies

- Complaints
- Maintenance
- Alerts
- Optimization
Normal Intersection Example: Phase Termination Chart

- 8-phase signal with working detection

### Metric: Phase Termination Chart
Detection Requirements: None
Complaint Example: Red light too long

- Max recall was placed for broken NB detection

Metric: Phase Termination Chart
Detection Requirements: None
Complaint Example: Red light too long

- Max recall was placed for broken NB detection

NB movement gets 75 sec of green time at night!

Metric: Split Monitor
Detection Requirements: None
Complaint Example:
Red light too long
- Max recall was placed for broken NB detection

Current operation

Check normal operation from previous month

March 5, 2014

Metric: Split Monitor
Detection Requirements: None
Complaint Example: Red light too long

- Max recall was placed for broken NB detection

Reduce max time to mimic typical operation

Previous operation

Metric: Split Monitor
Detection Requirements: None
Complaint Example: Split too short

Is this a timing or a maintenance issue?

Timing Issue:
Phase always forces off
=> Phase is using all programmed time

Maintenance Issue:
Phase often gaps out
=> Spotty right-turn lane detection

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

Metric: Split Monitor
Detection Requirements: None
Complaint Example: Phase skipped

SPMs confirm it was a fluke

Phase 8 skipped

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

Metric: Purdue Phase Termination Detection Requirements: None
Maintenance Example: Nighttime detection problem

BEFORE: Video detection not working at night

Metric: Purdue Phase Termination
Detection Requirements: None
Maintenance Example: Nighttime detection problem

- AFTER: New detection technology installed

Phases are rarely used at night

Metric: Purdue Phase Termination
Detection Requirements: None
Maintenance Example: Check for additional problems

- Phase 2 ped problem was not noticed at field visit

10/14/2013: Problems with Phase 8, Phase 3, & Phase 2 ped

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

Metric: Purdue Phase Termination Detection Requirements: None
Maintenance Example: Check for additional problems

- Phase 2 ped problem was not noticed at field visit

10/21/2013: Phase 3 & 8 problems were fixed, but not Phase 2 ped

Metric: Purdue Phase Termination Detection Requirements: None

Gap out

Pedestrian activation
(shown above phase line)

Max out

Force off

Skip
Maintenance Example: Detection Upgrade Justification

- Document recurring detection problems

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.
- Compare to previous day’s list. Only phases with new flags are sent in the email.

Metric: Purdue Phase Termination
Detection Requirements: None
Alert Example: 100% Max Out

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

- Phase 4 starts constant call
- SPMS evaluated for % max outs
- Phase 4 included in Alert email

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

Metric: Purdue Phase Termination
Detection Requirements: None
Optimization Example: Oversize Peds

Check frequency of ped calls

- 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

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

**Traditional Process**

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

**Modified Process with SPMs**

1. Review SPMs
2. Field Observation
3. Model Time-space Diagram
4. Optimize
5. Review SPMs
6. Implement & Fine-tune
Before and After Coordination Results

Corridor: Bangerter Hwy, SLC
To/From: SR-201 - 6200 South
Date: March 2013
Time Period: PM Peak

Results:
- Arrivals on Green: 19% ↑
- NB TT Savings: 0.3 Minutes
- NB Reliability: 55% ↑
- SB TT Savings: 1.1 Minute
- SB Reliability: 52% ↑

Metric 1: Purdue Coordination Diagram
Detection Requirements: Advance

Metric 2: Purdue Travel Time Diagram
Requirements: Probe data set
AUTOMATED TRAFFIC SIGNAL PERFORMANCE MEASURES
CASE STUDIES: INDOT

INSTITUTE OF TRANSPORTATION ENGINEERS WEBINAR PART 1 – MAY 7, 2014
PRESENTED BY AMANDA STEVENS, INDOT AND ALEX HAINEN, PURDUE
### Active Phase Events:

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<thead>
<tr>
<th>Code</th>
<th>Event Description</th>
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<tbody>
<tr>
<td>0</td>
<td>Phase On</td>
</tr>
<tr>
<td>1</td>
<td>Phase Begin Green</td>
</tr>
<tr>
<td>2</td>
<td>Phase Check</td>
</tr>
<tr>
<td>3</td>
<td>Phase Min Complete</td>
</tr>
<tr>
<td>4</td>
<td>Phase Gap Out</td>
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<tr>
<td>5</td>
<td>Phase Max Out</td>
</tr>
<tr>
<td>6</td>
<td>Phase Force Off</td>
</tr>
<tr>
<td>7</td>
<td>Phase Green Termination</td>
</tr>
<tr>
<td>8</td>
<td>Phase Begin Yellow Clearance</td>
</tr>
<tr>
<td>9</td>
<td>Phase End Yellow Clearance</td>
</tr>
<tr>
<td>10</td>
<td>Phase Begin Red Clearance</td>
</tr>
<tr>
<td>11</td>
<td>Phase End Red Clearance</td>
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### Detector Events:

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<th>Event Description</th>
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<tr>
<td>81</td>
<td>Detector Off</td>
</tr>
<tr>
<td>82</td>
<td>Detector On</td>
</tr>
<tr>
<td>83</td>
<td>Detector Restored</td>
</tr>
<tr>
<td>84</td>
<td>Detector Fault- Other</td>
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<tr>
<td>85</td>
<td>Detector Fault- Watchdog Fault</td>
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<tr>
<td>86</td>
<td>Detector Fault- Open Loop Fault</td>
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### Preemption Events:

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<tr>
<td>101</td>
<td>Preempt Advance Warning Input</td>
</tr>
<tr>
<td>102</td>
<td>Preempt (Call) Input On</td>
</tr>
<tr>
<td>103</td>
<td>Preempt Gate Down Input Received</td>
</tr>
<tr>
<td>104</td>
<td>Preempt (Call) Input Off</td>
</tr>
<tr>
<td>105</td>
<td>Preempt Entry Entry Started</td>
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</table>

**Controller Enumerations**

Event Code, Event Description, Parameter
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<th>Parameter</th>
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<tr>
<td>06/27/2013 01:29:52.2</td>
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<tr>
<td>06/27/2013 01:30:27.5</td>
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</tr>
<tr>
<td>06/27/2013 01:30:30.4</td>
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</tr>
</tbody>
</table>
Purdue Coordination Diagram: Red Arrival
Purdue Coordination Diagram: Green Arrival
PCD: Platoon Arrival by TOD
PCD: Adjust Offsets
INDOT System

- # SIGNALS TOTAL
- # SIGNALS ONLINE, AUTOMATICALLY STORING DATA & GENERATING PERFORMANCE MEASURE GRAPHS
- PEEK ATC, ECONOLITE ASC/3, SIEMENS M50 SERIES…
“Human-in-the-Loop-Adaptive”

- WEEKENDS & OFF-Peaks
- ROUTINE RETIMINGS
- CONSTRUCTION SEASON:
  - You cannot be everywhere at once!
  - Could take Months for traffic to settle
  - Project in Flux:
    - Detection
    - Phases
    - Approaches / Lanes
    - Adjacent construction detours
Moving Forward:

• Closely-spaced signals also need advanced detection on left turns

• Separate detection channels for each lane
PCD: Cycle Failure

- **PCD**: Cycle Failure
- **Time in Cycle (s)**
- **Time of Day (h)**

[Diagram showing data points and graph analysis]
PCD: Pattern Start & End Times
Hi-resolution Event-based Data for Diamond Interchange Operations

ALEX HAINEN
AMANDA STEVENS
CHRIS DAY
RICK FREIJE

JIM STURDEVANT
DARCY BULLOCK
HOWELL LI
Diamond Interchanges
What are they and why do they matter?

Normal Intersection

Diamond Interchange
Diamond Interchanges

*Indiana = 161 Interchanges
Nationally >= 10,000*
I-465 @ SR-37
Diamond Interchange w/Advanced Loops
Phasing

Two “T”-Intersections Treated Independently

Ø6 is the coordinated phase

Ø2 is the coordinated phase
Ring Displacement
Offset Between Coordinated Phases

Ring 1

3
1
2*

Ring 2

7
5
6*

RD = 42s
Ring Structure

From the HiRes Data, Plot the Rings

North INT

South INT

OL-H

OL-D

Ø6+Ø7

Ø2+Ø3

Ring Displacement

How is this parameter set?

COORDINATOR PATTERN [1] ~

TS2 (PATT-OFF) 0-1
CYCLE........ 0s STD (COS)......111
OFFSET VAL.... 0s DWELL/ADD TIME: 0
ACTUATED COORD... NO TIMING PLAN... &
ACT WALK REST.... NO SEQUENCE.........
PHASE RESRUE.... NO ACTION PLAN..%
MAX SELECT..... NONE FORCE OFF.... NONE
SPLIT PREFERENCE PHASES

DIAL 1 SPLIT 1 PARAMETERS
OFFSET TIME ALT PATN R2 R3 R4
# SEC SEQ MODE LAG LAG LAG
1 0 0 0
2 0 0 0
3 0 0 0

MODE (0-6) : NRM/PRM/YLD/PYL/POM/SOM/FAC
A-UP B-DN C-LT D-RT E-ENTER F-PRIOR MENU

Ring Displacement

Ring Displacement

Ring Displacement

Ring Displacement

Ring Displacement

Ring Displacement

Ring Displacement

Ring Displacement

Ring Displacement

Ring Displacement
SB Thru Detectors

Consider one of the four internal movements.
Arrival on Green?
Plot the green status of the overlap
Project the Detector Data

295’ upstream ≈ 5 seconds @ 40 MPH

The engineer who set the ring displacement did a fantastic job at arrivals on green for this movement!
Upstream Source Phase?

Look upstream ~10 seconds at the signal phase
Now Platoons are Attributed to a Phase
The vehicles’ sources are known
Traffic from SBT
Vehicles from Ø6

Southbound Traffic from Ø6 at the north intersection heading to the south intersection
Traffic from WBL
Vehicles from Ø7

Westbound Left Traffic from Ø7 off the ramp at the north intersection heading to the south intersection
Adjusting the ring displacement
What effect would it have?
Ring Displacement +10 Seconds
What effect would it have?
Ring Displacement +20 Seconds
Vehicles from upstream arrive later
By moving the ring displacement 20 seconds forward, the lagging WBL from the north ramp movement arrives at the south intersection on OL-D red while the EBL at the south ramp is served... Not Good!
Optimization Curves
Let's Look at the Southbound Thru (Our +0, +10, +20 example)
Optimization Curves
Southbound Thru +10

Percent on Green vs. Ring Displacement Adjustment

- SB Thru

Optimization curves showing the relationship between percent on green and ring displacement adjustment for Southbound Thru +10.
Optimization Curves
Southbound Thru +20

Percent on Green

Ring Displacement Adjustment
Optimization Consideration
Consider All 4 Movements Simultaneously
Optimization Curves
Southbound Thru +20

Ring Displacement Adjustment vs. Percent on Green
Optimization Curves
Southbound Thru for the Full Sweep

Percent on Green vs. Ring Displacement Adjustment
Optimization Curves
Northbound Left

Ring Displacement Adjustment

Percent on Green

- SB Thru
- NB Thru
- SB Left
- NB Left

[Graph showing curves for different traffic directions and ring displacement adjustments]
Composite Interchange Sweep

This is where all four movements are considered simultaneously.

![Composite Interchange Sweep Graph]

Legend:
- **SB Thru**
- **NB Thru**
- **SB Left**
- **NB Left**
- **Composite**

**Percent on Green**

**Ring Displacement Adjustment**
Field Evaluation

Adjust +/- 10 to see how it worked in the field

```
July 10: RD = -10  
Predicted: 8.5%  
Actual: 71.0%
```

```
July 11: RD = +10  
Predicted: 3.6%  
Actual: 68.8%
```
Purdue Coordination Diagram

Also Useful to Visualize Arrivals on Green
Purdue Coordination Diagram
Looking at an entire plan (0900-1400)
24HR PCD: Sequence for 0900-1400

First is Ø6 SBT, then Ø7 WBL from the ramp
24HR PCD: Sequence for 1400-1900

First is Ø7 WBL from the ramp, then Ø6 SBT

Ramp then Thru
Conclusion: These Graphics are Useful!
Can they be included on newer generation traffic controllers?
Conclusion: These Graphics are Useful!

Can they be included on newer generation traffic controllers?
AUTOMATED TRAFFIC SIGNAL PERFORMANCE MEASURES
CASE STUDIES: MnDOT

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PRESENTED BY STEVE MISGEN, MNDOT
MnDOT - Metro District Background

- Operates about 700 signals (Mpls/St. Paul Metro area)
  - 250 signal on i2 central system
  - 450 on ARIES dial-up
- Econolite ASC2/ASC2S or ASC3 controllers
- Signal Performance Measure
  - 83 on Smart Signal
  - 21 on Utah SPM
Smart Signal

- University of Minnesota
  - Henry Liu
- Minnesota Department of Transportation
- http://dotapp7.dot.state.mn.us/smartsignal
  - iMonitor – “Real-time” Level of Service
  - iMeasure – Data extraction tool
The Project
Develop New Timing Using High Resolution Data collected from SmartSignal

- 4 fully-actuated signals
- High speed 60-65 mph posted
- 33,000-68,000 AADT
- 7 TOD plans
- Last retimed 2009
Signal Timing Development

Standard Method
- Data Collection
  - Manual Turning Movement Count – 12 hour
  - System Detectors
- Synchro – approximation of splits & cycle lengths
- Implementation & fine turning completed by time space diagram and field observations
- Before/After Comparison using Travel Time Studies

Improved Method
- Data Collection
  - Automated collection averaged over Sept-Oct for each movement (M-Th, F, S & S)
- Synchro - Time-space diagram for best two-way progression
- Implementation & fine turning completed by time-space diagram and field observations
- Smart Signal – monitor and make adjustments to insure efficiency
- Before/After Comparison using signal performance metrics
Volumes

September/October 2013 85th % Weekday Volumes - TH 10 at Thurston Avenue

Traffic Volume (15-min period) vs. Time of Day

- EB 10/17
- WB 10/17
- WB
- EB
Peak Periods Before/After Performance Comparison

Total Delay (Hours)

Number of Stops

<table>
<thead>
<tr>
<th></th>
<th>AM</th>
<th>Mid-Day</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Mid-Day</td>
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<td></td>
</tr>
<tr>
<td>PM</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Peak Periods Before/After Performance Comparison

Max Queue Length (Ft)

- AM
- Mid-Day
- PM

Saturation Level

- AM
- Mid Day
- PM
Future Plans

- **Performance Index**
  - based on volume, delay, number of stops, max queue length, saturation level & percent of vehicles arriving on Green
  - Calculate the PI for a given period on time (PM Peak) over a period of time (every Wednesday for the past year)
  - Track the change on performance over time
    - *When do you need to retiming!*

- **Time-space Diagram**
  - Real-time TSD based on detector actuations

- **Performance Metrics**
  - Emissions – CO$_2$ fuel consumed
MnDOT Signal Performance Measures

Steve Misgen, PE, PTOE
MnDOT – Metro District
Traffic Engineer
Steve.misgen@state.mn.us
Find out more:
http://tig.transportation.org
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  April 9, 2014, 12:00 pm to 1:30 pm. Eastern

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- Critical Infrastructure Elements for SPMs
  June 11, 2014, 12:00 pm to 1:30 pm. Eastern
Thank you.

QUESTIONS?

http://tig.transportation.org
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