AUTOMATED TRAFFIC SIGNAL PERFORMANCE MEASURES: Critical Infrastructure Elements for SPMs

INSTITUTE OF TRANSPORTATION ENGINEERS WEBINAR PART 3 – JUNE 11, 2014
ITE Webinar Series on Automated Traffic Signal Performance Measures (SPMs)

- 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

Shane Johnson, UDOT
Dr. Chris Day, Purdue
Howell Li, Purdue
Questions for the audience

- How many signals are under your jurisdiction?
- What types of vehicle detection are used at your intersections?
- Are there any communication infrastructure connecting your cabinets?
- What operating system platform(s) do you use (Windows, Linux, Mac)?
- What are some of your biggest challenges for enabling performance metrics in your area?
CRITICAL INFRASTRUCTURE ELEMENTS: Background

INSTITUTE OF TRANSPORTATION ENGINEERS WEBINAR PART 3 – JUNE 11, 2014
PRESENTED BY DR. CHRIS DAY
Overview

- Background on Automated Traffic Signal Performance Measures
- Hierarchy of Infrastructure Requirements
  - Communications
  - Detection
- Data Infrastructure for Agency Implementation
  - Utah DOT
  - Indiana DOT
Why Measure Traffic Signal Performance?

- Better respond to user complaints
  - Verify whether reported problems occur
  - Identify solutions
- Proactively identify and correct operational and maintenance inefficiencies
  - Improve quality of progression
  - Improve capacity allocation
Motivation

- Average values versus full event timeline
- When is intervention needed?
Legacy Data Collection:
15-Minute Average Detector Occupancy
What Is “High Resolution” Data?

Vehicle and Pedestrian Activity

Detection

Events

Performance Measures

Events

Control System

Control Decisions
What Is “High Resolution” Data?

<table>
<thead>
<tr>
<th>Time</th>
<th>1</th>
<th>2</th>
<th>3</th>
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<th>5</th>
<th>6</th>
<th>7</th>
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<tbody>
<tr>
<td>Count</td>
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</tr>
</tbody>
</table>

The diagram illustrates time intervals for counting vehicles and their presence, along with traffic light signals R (red), Y (yellow), and G (green).
What Is “High Resolution” Data?

<table>
<thead>
<tr>
<th>Count</th>
<th>Presence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
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<tr>
<td>2</td>
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<td>9</td>
<td></td>
</tr>
</tbody>
</table>

- **R** Event 82 Detector On
- **Y** Event 81 Detector Off

**Time**
What Is “High Resolution” Data?

Time

Count

R

Y

G

Presence

1 2 3 4 5

Event 10
Start Red
Clear

Event 8
Start Yellow
Clear

Event 0
End Red
Clear

Event 1
Start of
Green
What Is “High Resolution” Data?

<table>
<thead>
<tr>
<th>Count</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
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<tr>
<td>Presence</td>
<td></td>
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<tr>
<td>R</td>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Y</td>
<td></td>
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<tr>
<td>G</td>
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<td></td>
</tr>
</tbody>
</table>

9 vehicles
20 seconds of green
v/c ratio 0.9
Cycle-by-Cycle Performance Measures

Phase 2, Westbound
Cycle-by-Cycle Performance Measures

- **Φ1**: Eastbound Left
- **Φ2**: Westbound
- **Φ3**: Northbound Left
- **Φ4**: Southbound
- **Φ5**: Westbound Left
- **Φ6**: Eastbound
- **Φ7**: Southbound Left
- **Φ8**: Northbound

### Time of Day

#### Volume-to-Capacity Ratio

- **0:00**
- **6:00**
- **12:00**
- **18:00**
- **0:00**
History of Development

- Manual Data Collection
  - 5, 15 minute averages

- Monitoring Load Switch Circuits
  - High-resolution data
  - Latency and clock drift issues
  - “Do-it-yourself” data collection

- Embedded Controller Data Collector
  - Record controller events that do not correspond to circuit closures
  - Required vendor buy-in
Hardware-in-the-Loop Simulation

Data:
- Signal Indications
- Detector Events
- Coordination Events
Field Data Collection Using Industrial I/O Equipment

Data:
- Signal Indications
- Detector Events
- Coordination Events
Field Data Collection Cabinet

Detector Status

Autoscope Solo Pro as Data Collector
(8 input channels per camera)

Load Switch Status
Field Data Collection Cabinet

PC with remote desktop over DSL

Autoscopes
Pilot Test of Controller Data Logger (Fall 2006)

ASC/2 operating the intersection

ASC/3 with same inputs but no control output
Objective: Vendor Neutrality
Development of Controller Data Enumerations

- Want to ensure that a “Phase 2 Green” is written down the same way in every vendor’s controller
- Invited controller manufacturers to collaborate to agree on a specification for the data
- Three vendors initially participated
- Today, five vendors have implemented a controller data logger
### Controller Enumerations

**Active Phase Events:**

<table>
<thead>
<tr>
<th>Event Code</th>
<th>Event Description</th>
</tr>
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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>
</tr>
<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>
</tr>
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</table>

**Detector Events:**

<table>
<thead>
<tr>
<th>Event Code</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<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>
</tr>
<tr>
<td>85</td>
<td>Detector Fault- Watchdog Fault</td>
</tr>
<tr>
<td>86</td>
<td>Detector Fault- Open Loop Fault</td>
</tr>
</tbody>
</table>

**Preemption Events:**

<table>
<thead>
<tr>
<th>Event Code</th>
<th>Event Description</th>
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<tbody>
<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 Started</td>
</tr>
<tr>
<td>Timestamp</td>
<td>Enumeration Code</td>
</tr>
<tr>
<td>--------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>06/27/2013 01:29:51.1</td>
<td>10</td>
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<td>06/27/2013 01:29:51.1</td>
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<tr>
<td>06/27/2013 01:29:52.2</td>
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<tr>
<td>06/27/2013 01:29:52.2</td>
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<tr>
<td>06/27/2013 01:29:52.3</td>
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<td>81</td>
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<tr>
<td>06/27/2013 01:30:30.4</td>
<td>8</td>
</tr>
</tbody>
</table>
Controllers with High Resolution Data Loggers (As of 2014)

- Econolite
- Peek
- Siemens
- Intelight
- Trafficware (Naztec)
Hierarchy of Infrastructure Needs

1. Detection
   - Detector Health
2. Communications
   - Working Communications
3. Operations
   - Efficient Local Control
   - Efficient Coordination
System Requirements

High-resolution Controller

Communications

Server

Website

Detection (optional)

Photo courtesy of the Indiana Department of Transportation
Communications

- Needed to bring data from the field to the office to develop performance measures
Communications

Methods of Data Transport
- Fiber Interconnect
- Cellular Modem
- “Sneaker-net”
Example Communications Infrastructure

Zone 1
- Individual cabinet wireless connections

Zone 2
- Local fiber network and single point wireless connection

Traffic Management Center
- Signal Events
- SQL Query

Commercial IP Cellular Network

Agency-Wide Signal Network

Performance Measures
NCHRP 3-79A

Network, Intersection, and Detector Geometry
Example Communications Infrastructure
Example Communications Infrastructure

Zone 2

Local fiber network and single point wireless connection

Internet (Virtual Private Network)
What About Locations Without a Connection?

Switch

Controller

Single Board PC

Copying Data...
Detection Requirements

- Need some kind of detection on each movement that is desired to be analyzed
  - Any detection technology can be used (provided that it works)
- Flexible – Existing detection is often adequate
- Count detection allows more detailed analysis, but not required
Stopbar versus Advance Detection

- **Stop bar detection**
  - Measure vehicles as they are served
  - Useful for measuring utilization of capacity for individual movements

- **Advance detection**
  - Measure vehicles as they arrive at the intersection
  - Needed to evaluate progression
  - Can also evaluate utilization of capacity
Presence versus Count Detection

- When detection zone is longer than the length of a typical vehicle

  - **Option 1 – Presence Only**
    - Measure detector occupancy

  - **Option 2 – Presence with Count**
    - May require special detector equipment (e.g., count amplifier for loops)
    - Measure volume of vehicles
Detection Types That Have Been Used

- Inductive Loop
- Radar
- Video
- Magnetometer
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 Presence Detection
- Split Failure (future)

Lane-by-lane Count Detection
- Turning Movement Counts

Probe Travel Time Data (GPS or Bluetooth)
- Purdue Travel Time Diagram
Example Applications of Performance Measures

1. Capacity Allocation
   - Split Failure and Split Adjustment

2. Quality of Progression
   - Offset Optimization
Coordination Diagram

\[ P = \frac{N_g}{N} \]
Coordination Diagram
24-Hour View

Vehicle Arrivals

End of Green

Beginning of Green

Beginning of Cycle (red)
Modeling Changes to Offset

BEFORE

PREDICTED

AFTER
Offset Optimization Case Study

- Int. 1 (SR 32)
- Int. 2 (Pleasant St.)
- Int. 3 (Town and Country Blvd.)
- Int. 4 (Greenfield Ave.)
- Int. 5 (146th St.)
- Int. 6 (141st St.)
- Int. 7 (131st St.)
- Int. 8 (126th St.)

System 1:
- 2.4 mi (3.8 km)
- 2300 ft (700 m)
- 2500 ft (760 m)
- 3660 ft (1110 m)

System 2:
- 2.8 mi (4.5 km)
- 8350 ft (2530 m)
- 5320 ft (1610 m)

System 3:
- 8350 ft (2530 m)

BT Case A
- 2650 ft (800 m)

BT Case B
- 2650 ft (800 m)

BT Case C
- 8350 ft (2530 m)
Offset Optimization – BEFORE

System 1

System 2

5SB
Bad

6SB
Bad
Offset Optimization – AFTER

System 1

System 2
Impact on Travel Times

I. Min Delay
II. Min Delay / Stops
III. Max Arrivals on Green
IV. Max Arrivals on Green with Queue Clearance
Impact on Travel Times

Southbound Travel Time

Northbound Travel Time

Travel Time (min)

Travel Time (min)
## Estimation of User Benefit

### Objective

<table>
<thead>
<tr>
<th>Objective</th>
<th>Daily</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Time Saved (veh-min)</td>
<td>CO$_2$ Emission Reduction (tons)</td>
</tr>
<tr>
<td>I</td>
<td>Min Delay</td>
<td>5032</td>
</tr>
<tr>
<td>II</td>
<td>Min Delay and Stops</td>
<td>3813</td>
</tr>
<tr>
<td>III</td>
<td>Max $N_g$</td>
<td>1760</td>
</tr>
<tr>
<td>IV</td>
<td>Alt. Max $N_g$</td>
<td>7883</td>
</tr>
</tbody>
</table>

### Impact of going from arrivals in red to arrivals in green

- I (Min Delay): $810 → $1,697
- II (Min Delay and Stops): $614 → $1,286
- III (Max $N_g$): $283 → $593
- IV (Alt. Max $N_g$): $1,268 → $2,658

### Notes

- Impact varies significantly depending on the objective and system section.
- The table provides a comprehensive view of user benefits and CO$_2$ emissions for different scenarios.
- Economic values are calculated as the product of time savings and per-vehicle cost.

---

### System 2, Southern Section

- I (Min Delay): $3,924 → $8,223
- II (Min Delay and Stops): $4,075 → $8,541
- III (Max $N_g$): $4,046 → $8,480
- IV (Alt. Max $N_g$): $4,238 → $8,882

### System 1 and System 2, Arterial

- I (Min Delay): $4,733 → $9,920
- II (Min Delay and Stops): $4,689 → $9,826
- III (Max $N_g$): $4,329 → $9,073
- IV (Alt. Max $N_g$): $5,506 → $11,540

---

Impact of going from arrivals in red to arrivals in green
Agencies using UDOT software for SPMs

http://udottraffic.utah.gov/signalperformancemetrics
Detector Activations and Poll Rates.

1 Polling Cycle (1 Second)

POLL RESPONSE

Controller Creates Response

Detector Activations

Only this activation gets recorded
Detector Activations and Poll Rates.

Only **this** activation gets recorded.

3 Polling Cycles in 1 Second
The Econolite ASC3 Controller

- Collects events at 1/10 second resolution
- Stores the collected events in binary log files for maximum storage efficiency
- The files are retrieved over FTP
- UDOT uses APP version 2.54 and OS version 1.14.03.
Detection Technologies

Setback Count Detectors

- Wavetronix Advance
- Used to timestamp vehicle arrivals
- 10’ count zone placed ~350’ behind stop bar
- No additional expense if already in place for dilemma zones
- May undercount dense traffic
Loops

- We have one site that uses loops for advanced detection.
- The loops come in on separate detection channels. They are combined together in the SPM software to give accurate counts.
Detection Technologies

- Uses the Wavetronix Advance
- The detector sends the recorded MPH, KPH, timestamp and detector ID to a server.
- The server records the information to the database for use in the charts.
Wavetronix Matrix detectors

- Used for turning movement counts
- Lane-by-lane detection zones in front of stop bar
- Requires detection rack card for every two zones ($$$$
- Wavetronix is expected to release a new high-capacity detector BIU in June, 2014.
Detection Technologies

Standard stop bar detection

- The intersection can still be monitored with the Phase Termination and Split Phase charts.
Communication

- UDOT has the advantage of fiber Ethernet to nearly every signal cabinet in the state.
- This provides fast and reliable communication, making the wide-scale rapid collection of hi-res data feasible.
- Even so, event collection is typically 7-10 minutes behind real time.
In the locations we lack fiber, DSL provides a connection to a fiber channel.

In the few sites that remain, we are investigating “Sneaker-Net” solutions, such as the Raspberry Pi.
Each intersection must have a unique identifier.

UDOT uses 4-digit ID numbers that have been assigned by region to every intersection in the state.
The controller times must be synched, or the events do not make much sense.

It is possible to synchronize the time on NTCIP controllers without a central signal system.
Enabling the Hi-Res Logger

- Logging on the ASC3 controllers can be enabled and disabled over SNMP. There is no option for it through the front panel.
- VOIT logging, if enabled, must be disabled first.
- If the controller is reset, logging must be enabled again.
The ASC3 records each event in 1/10 second resolution.

The events are stored in binary .dat files on the controller.

The binary format significantly reduces the amount of storage space required on the controller.
The Econolite binary file

Before:

• The binary file is not easily readable.
• It can be translated to csv.
• Econolite has created a log translator program.

After:

• The decoded CSV is nearly 8 times larger than the encoded binary file.
Retrieving the binary file

- The ASC3 controllers have FTP servers.
- The .dat files are located in the /SET1 directory.
- A program periodically collects the .dat files from the controller using FTP, and stores the files in on the database server.
The .CSV file

- The controller does not know its own ID.
- Therefore, the Signal ID is nowhere in the .csv file.
- That information must be added to the record before it is added to the database.
The Event Database

- Each record in the CSV must have the signal ID added to it.
- The record can then be added to the database.
- On average, each intersection will need 11MB per day.
- UDOT requires 11 GB per day to hold the collected controller events.
• The Event log contains four pieces of information: SignalID, Timestamp, Event Code and Event Parameter.

• The entry for a detector activation would look like:

1001, 01/01/2014 12:37 33:20, 82, 12

• The last two values are the Event code (82) and the Event Parameter (12)

• Event Code 82 indicates a detector activation on detector channel 12 (the Event Parameter)
Why the Schema Matters

- We need a way to relate signal ID and detector channel to approach direction and phase number.
- The controller does not have this information.
- That is why we need a list of Detectors

<table>
<thead>
<tr>
<th>Detectors Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>DetectorID</td>
</tr>
<tr>
<td>SignalID</td>
</tr>
<tr>
<td>DetectorChannel</td>
</tr>
<tr>
<td>Approach Direction</td>
</tr>
<tr>
<td>Associated Phase</td>
</tr>
<tr>
<td>AvailableReports</td>
</tr>
</tbody>
</table>
Why the Schema Matters

**Signal Table**
- SignalID
- PrimaryName
- SecondaryName
- ControllerType
- Longitude
- Latitude
- IPAddress
What you will need

- A Database server
- Microsoft SQL server 2008 or later
- Microsoft Windows server 2008 R2 or later
- Disk space requirements will vary, but you will want a lot (We started with 8 TB, and we are running out)
- The more processors you can get, the happier you will be.
What you will need

- A Web Server
- Windows Server 2008 R2 or later
- Internet Information Server 7.0 or later
- Faster processors and more RAM will provide a more responsive experience.
- Hard drive requirements for the web server are minimal
Hardware Mitigation

- Reduce storage requirements by deleting old data. (Do you really need to know when a car crossed a detector 3 years ago?)

- Archive old records to tape or other media, and restore it when needed. (It might be best to do this in a .CSV format instead of a database backup)
Hardware Mitigation

- The UDOT SPM system can be hosted on multiple smaller computers, instead of one large and expensive one.
- The hard drive requirements will still be large, however.
# Probe Data

## Cumulative Frequency Chart

<table>
<thead>
<tr>
<th>TMC Code</th>
<th>TMC Name</th>
<th>Range ID</th>
<th>Time Range</th>
<th>TMC Length</th>
<th>Avg. Travel Time</th>
<th>Std. Dev</th>
<th>% Good Bins</th>
<th>Avg. Confidence Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>116+05725</td>
<td>Bangerter From: 12600 S To: 3000 S</td>
<td>1</td>
<td>1/6/2014 - 1/7/2014 From: 5:00 PM To: 6:00 PM</td>
<td>4.6</td>
<td>6.64</td>
<td>0.51</td>
<td>94%</td>
<td>30</td>
</tr>
<tr>
<td>116+05725</td>
<td>Bangerter From: 12600 S To: 3000 S</td>
<td>2</td>
<td>2/27/2014 - 2/7/2014 From: 5:00 PM To: 6:00 PM</td>
<td>4.6</td>
<td>5.95</td>
<td>0.43</td>
<td>92%</td>
<td>30</td>
</tr>
<tr>
<td>116+05725</td>
<td>Bangerter From: 12600 S To: 3000 S</td>
<td>3</td>
<td>2/2/2014 - 2/7/2014 From: 5:00 PM To: 6:00 PM</td>
<td>4.6</td>
<td>6.18</td>
<td>0.47</td>
<td>92%</td>
<td>30</td>
</tr>
<tr>
<td>116+05726</td>
<td>Bangerter From: 9000 S To: 7800 S</td>
<td>1</td>
<td>1/6/2014 - 1/7/2014 From: 5:00 PM To: 6:00 PM</td>
<td>1.4</td>
<td>1.75</td>
<td>0.20</td>
<td>84%</td>
<td>30</td>
</tr>
<tr>
<td>116+05726</td>
<td>Bangerter From: 9000 S To: 7800 S</td>
<td>2</td>
<td>2/27/2014 - 2/7/2014 From: 5:00 PM To: 6:00 PM</td>
<td>1.46</td>
<td>1.77</td>
<td>0.26</td>
<td>65%</td>
<td>30</td>
</tr>
<tr>
<td>116+05726</td>
<td>Bangerter From: 9000 S To: 7800 S</td>
<td>3</td>
<td>2/2/2014 - 2/7/2014 From: 5:00 PM To: 6:00 PM</td>
<td>1.46</td>
<td>1.78</td>
<td>0.22</td>
<td>69%</td>
<td>30</td>
</tr>
<tr>
<td>116+05727</td>
<td>Bangerter From: 7800 S To: 7000 S</td>
<td>1</td>
<td>1/6/2014 - 1/7/2014 From: 5:00 PM To: 6:00 PM</td>
<td>1</td>
<td>1.27</td>
<td>0.16</td>
<td>91%</td>
<td>30</td>
</tr>
<tr>
<td>116+05727</td>
<td>Bangerter From: 7800 S To: 7000 S</td>
<td>2</td>
<td>2/27/2014 - 2/7/2014 From: 5:00 PM To: 6:00 PM</td>
<td>1</td>
<td>1.30</td>
<td>0.20</td>
<td>77%</td>
<td>30</td>
</tr>
<tr>
<td>116+05727</td>
<td>Bangerter From: 7800 S To: 7000 S</td>
<td>3</td>
<td>2/2/2014 - 2/7/2014 From: 5:00 PM To: 6:00 PM</td>
<td>1</td>
<td>1.35</td>
<td>0.30</td>
<td>88%</td>
<td>30</td>
</tr>
<tr>
<td>116+05728</td>
<td>Bangerter From: 7000 S To: 6200 S</td>
<td>1</td>
<td>1/6/2014 - 1/7/2014 From: 5:00 PM To: 6:00 PM</td>
<td>0.92</td>
<td>1.23</td>
<td>0.20</td>
<td>88%</td>
<td>30</td>
</tr>
<tr>
<td>116+05728</td>
<td>Bangerter From: 7000 S To: 6200 S</td>
<td>2</td>
<td>2/27/2014 - 2/7/2014 From: 5:00 PM To: 6:00 PM</td>
<td>0.92</td>
<td>1.37</td>
<td>0.43</td>
<td>79%</td>
<td>30</td>
</tr>
<tr>
<td>116+05728</td>
<td>Bangerter From: 7000 S To: 6200 S</td>
<td>3</td>
<td>2/2/2014 - 2/7/2014 From: 5:00 PM To: 6:00 PM</td>
<td>0.92</td>
<td>1.49</td>
<td>0.55</td>
<td>89%</td>
<td>30</td>
</tr>
<tr>
<td>116+05729</td>
<td>Bangerter From: 6200 S To: 5400 S</td>
<td>1</td>
<td>1/6/2014 - 1/7/2014 From: 5:00 PM To: 6:00 PM</td>
<td>1.04</td>
<td>1.39</td>
<td>0.13</td>
<td>69%</td>
<td>30</td>
</tr>
<tr>
<td>116+05729</td>
<td>Bangerter From: 6200 S To: 5400 S</td>
<td>2</td>
<td>2/27/2014 - 2/7/2014 From: 5:00 PM To: 6:00 PM</td>
<td>1.04</td>
<td>1.43</td>
<td>0.17</td>
<td>81%</td>
<td>30</td>
</tr>
<tr>
<td>116+05729</td>
<td>Bangerter From: 6200 S To: 5400 S</td>
<td>3</td>
<td>2/2/2014 - 2/7/2014 From: 5:00 PM To: 6:00 PM</td>
<td>1.04</td>
<td>1.45</td>
<td>0.19</td>
<td>92%</td>
<td>30</td>
</tr>
<tr>
<td>116+05730</td>
<td>Bangerter From: 5400 S To: 4700 S</td>
<td>1</td>
<td>1/6/2014 - 1/7/2014 From: 5:00 PM To: 6:00 PM</td>
<td>1.01</td>
<td>1.30</td>
<td>0.15</td>
<td>92%</td>
<td>30</td>
</tr>
</tbody>
</table>
Executive Summary
5/25/2014 to 5/25/2014

Statewide Summary

<table>
<thead>
<tr>
<th>Arrival on Red</th>
<th>Delay</th>
<th>Volume</th>
<th>Intersections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent</td>
<td>Platoon Ratio</td>
<td>Daily Average Per Approach (hrs)</td>
<td>Average Per Veh (sec)</td>
</tr>
<tr>
<td>29 %</td>
<td>2.72</td>
<td>0.01</td>
<td>6.18</td>
</tr>
</tbody>
</table>

Region Summary

<table>
<thead>
<tr>
<th>Region</th>
<th>Arrival on Red</th>
<th>Delay</th>
<th>Volume</th>
<th>Intersections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Percent</td>
<td>Platoon Ratio</td>
<td>Daily Average Per Approach (hrs)</td>
<td>Average Per Veh (sec)</td>
</tr>
<tr>
<td>1</td>
<td>20 %</td>
<td>14.47</td>
<td>0.00</td>
<td>1.68</td>
</tr>
<tr>
<td>2</td>
<td>29 %</td>
<td>1.50</td>
<td>0.03</td>
<td>6.45</td>
</tr>
<tr>
<td>3</td>
<td>26 %</td>
<td>18.87</td>
<td>0.01</td>
<td>5.96</td>
</tr>
<tr>
<td>4</td>
<td>17 %</td>
<td>1.23</td>
<td>0.10</td>
<td>1.56</td>
</tr>
</tbody>
</table>
The UDOT SPM system is written in C#, Javascript and ASP.NET

At last count, more than 90,000 lines of code went into the system (that includes the auto-generated files that must be maintained)

As of June 1st, 2014, there were more than 53 billion records in the UDOT SPM Database
Trivia and Statistics

- Our database server, purchased in 2011, cost about $15,000. 80% of that cost was for hard drives.
- We are adding another 12 TB of drive capacity, which we hope will provide another 3.5 years of record storage.
- We estimate we have saved the state 1.5 million dollars so far, based on our ability to find broken detectors, optimize offsets and collect count information.
CRITICAL INFRASTRUCTURE ELEMENTS: INDOT Implementation

INSTITUTE OF TRANSPORTATION ENGINEERS WEBINAR PART 3 – JUNE 11, 2014
PRESENTED BY HOWELL LI
INDOT Signal Systems Network

- 2505 signals
- 196 signals with high-resolution data enabled
  - Mixed cellular, wireless, and fiber infrastructure
- Vendor-neutral system
- Open source software for back office
- Joint INDOT-Purdue software development
Cabinets and Controllers

- All performance measure-enabled cabinets are NEMA standard

<table>
<thead>
<tr>
<th>Make</th>
<th>Num. Connected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Econolite</td>
<td>188</td>
</tr>
<tr>
<td>Peek</td>
<td>7</td>
</tr>
<tr>
<td>Siemens</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>196</strong></td>
</tr>
</tbody>
</table>
Detection

Cut or pave-over loops

SDLC interface
Connection Methods

- **Hauling data back to the TMC**
  - Commercial cellular networks (public network)
    - Each subscription costs $34.99/mo
    - Recommend separate Virtual Private Network (VPN)
  - Wireless broadband and fiber backbone (private network)

- **Hauling data between cabinets**
  - Localized longitudinal fiber
  - Broadband or 900 mhz Ethernet radios

- Customize on location needs and costs

**INDOT Signals Connectivity**

![Chart showing cellular network and wireless broadband and fiber network connectivity with respective counts: Cellular Network = 122, Wireless Broadband and Fiber Network = 74.]
Commercial Cellular Networks

Data encrypted over VPN

Traffic Management Center Server

Cellular modem

VPN Router

Controller
Cabinet 1

Controller
Cabinet 2

Controller
Cabinet 3
Commercial Cellular Networks

VPN router (now integrated with RavenX)

RavenX Cell modem
Wireless Broadband and Fiber (no arterial fiber)
Wireless Broadband and Fiber Backbone

Base Station (Mounted on Tower)

Cabinet 1 (With subscriber unit)

Cabinet 2 (With subscriber unit)

Cabinet 3 (With subscriber unit)

Cabinet 4 (With subscriber unit)

Backbone fiber (to TMC)

Signal gets weaker with distance
Wireless Broadband and Fiber Backbone

Base Station (Mounted on Tower)

Arterial fiber (local)

Cabinet 1 (With subscriber unit)

Cabinet 2

Cabinet 3

Cabinet 4

Backbone fiber (to TMC)
Wireless Broadband and Backbone Fiber
Longitudinal Fiber with Cellular Backhaul

**Internet**

**Traffic Management Center Server**

**Controller**
- Cabinet 1
- Cabinet 2
- Cabinet 3

**Ethernet switch**
- Cellular modem
- VPN Router
- Fiber Interconnect

**Local arterial fiber**
900 mhz Ethernet radio with Cellular Backhaul
“Sneaker Net”

- Cost-effective solution to get data needed by performance measures
- Saves data on SD memory card (up to the size of the card)
- Requires occasional field visits for retrieval

No connection infrastructure needed
FTP File Retrieval

- FTP – File Transfer Protocol
  - Connect using FTP Client software (e.g. FileZilla)
  - Use FTP Client API to download files
    - API – Application Programming Interface
    - Automation
    - To include as part of a larger data processing system

Field testing
Production systems
Servers for a Production System

- **Processing Server**
  - Retrieves data files from controllers via FTP
  - Data decoding and massaging
  - Saves processed data to Database Server
- **Database Server**
  - Stores and distributes high-resolution data
- **Web Server**
  - Client-side interface
  - Generates performance measures

**Hardware Specification**
- Dell PowerEdge R710
- 2x Quad-Core Intel Xeon Processors
- 96 GB of RAM
- 3TB – 12TB disk storage (10,000 RPM drives, RAID)
Software – All open source

- **Operating System**
  - Ubuntu Linux (version 12.04 LTS)

- **Processing Server**
  - PHP scripting (version 5.3)
  - Vendor-supplied decoding software

- **Database Server**
  - PostgreSQL (version 9.1)
    - Relational Database Management System (RDBMS)

- **Web Server**
  - Apache HTTP Server (version 2.2)
  - PHP Scripting (version 5.3)
How each server is tasked

Processing server

- Decoder or Translator program
- Ingestion program
- Binary Archive
- CSV Archive
- Binary Files
- CSV Files
- Relational Database Management System

Web server

Performance Measures

Database server
Data Flow – From Field to User

Runs every 30 mins
Data Storage Requirements

- **High-volume intersection** (AADT ~80,000)
- **Low-volume intersection** (AADT ~15,000)
Data Storage Requirements

- High-volume intersection (AADT ~80,000)
- Low-volume intersection (AADT ~15,000)
Data Storage Requirements

- Data size contingent on intersection volumes
- Busy intersections = more detections = more data

- High-volume intersection (AADT ~80,000)
  - Detection data: 70%
  - Other data: 30%

- Low-volume intersection (AADT ~15,000)
  - Detection data: 58%
  - Other data: 42%
Data Storage Requirements
Data Storage Requirements

Gigabytes of Data (cumulative)

- **Actual size on database**
- **Raw data size** (FTP binary files from controller)
Database Schema

**System**
- **id** (int)
- **description** (varchar(255))

**Signal**
- **id** (int)
- **system_id** (smallint)
- **description** (varchar(255))
- **ip** (binary(4))
- **spatial** (geography)

**Controller Event Log**
- **signal_id** (int)
- **timestamp** (datetime)
- **code** (tinyint)
- **parameter** (tinyint)

**Route**
- **id** (int)
- **route_name** (varchar(255))

**Approach**
- **id** (int)
- **signal_id** (smallint)
- **route_direction** (smallint)
- **ordinal_position** (smallint)
- **route_id** (smallint)

**Detector**
- **id** (int)
- **signal_id** (smallint)
- **phase** (tinyint)
- **detector_number** (smallint)
- **count_number** (smallint)
- **loop_numbers** (varchar(255))
- **lane** (varchar(255))
- **local_direction** (smallint)

**Approach Detector Map**
- **approach_id** (int)
- **detector_id** (int)

Only for detector events.

Majority of data exists here: consider partitioning and compressing…
PCD

V/C Ratio

Split Failure graphs
Find out more:
http://tig.transportation.org

AASHTO's Technology Implementation Group — or TIG — scans the horizon for outstanding advances in technology and invests time and money to accelerate their adoption by agencies nationwide.

Each year, TIG selects a highly valuable, but largely unrecognized procedure, process, software, or tool that has been adopted by at least one agency, is market ready and is available for use by others.

Guided by the vision of "a culture where rapid advancement and implementation of high payoff, high expectation of the transportation community," TIG's objective is to share information with AASHTO agencies, and their industry partners to improve the Nation's transportation system.

Recently selected technologies with links to additional information are listed below. Also, you may view Lead States Team Focus Technologies and Additionally Selected Technologies categorized by AASHTO subcommittee interest area.

**Lead States Team Focus Technologies**

**2013 Focus Technologies**
- Automated Traffic Signal Performance Measures
- UPlan Phase II

**Prior Four Years Focus Technologies**
- Embedded Data Collector
- Environmental Planning GIS Tools

**Additionally Selected Technologies**

**2013 ASTs**
- Double Crossover Diagonal

**Prior Four Years ASTs**
- Anonymous Wireless Time Data Collection
- Curvature Extension for Road Cross Sections
-...
PERFORMANCE MEASURES FOR TRAFFIC SIGNAL SYSTEMS

An Outcome-Oriented Approach

http://tinyurl.com/signalmoe

DOI: 10.5703/1288284315333
Thank you.

COMMENTS OR QUESTIONS?

http://tig.transportation.org
http://tinyurl.com/signalmoe
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