Outline:

• Background and Motivation
• Performance Measures
  • Engineering vs Maintenance
• Detection Anomalies
• Split Failure Reports
  • Longitudinal
  • Intersection Level
• Conclusions
Motivation:

Limited staff time/funding available to monitor signal systems

Small % improvements in signal operations save large amounts in user delay costs

Modern controllers are fully capable computers able to record and report exactly what they were doing

Let the system monitor itself and/or give operator easy to use tools to check and adjust the system
User Delay Costs:

Sample of detector failure on a single signal phase

Phase 7 faulted (Max = 30 sec)
• 12.5 veh-h of delay increase per day
• 4560 veh-h of delay increase per year
• Using a $17 per hour value of travel time, this amounts to $78,000 per year in increased user cost

Phase 8 Faulted (Max = 40 sec)
• 55 veh-h of delay increase per day
• Approx. 20000 veh-h of delay increase per year
• $340,000 per year in increased user cost

• These examples are for single detector outages affecting one phase at one intersection. The goal of building the system is to avoid these occurrences at numerous detectors across many intersections.
Maintenance Performance Measures
Developed on two local agency systems in Indiana

Mishawaka
- 64 signals
- 37 reporting
- 22 with peds
- 1181 detection channels
- 6.6 M records per day

Elkhart County
- 29 signals
- 21 reporting
- 3 with peds
- 671 detection channels
- 2.7 M records per day
What do you need for performance measures?
What do you need for performance measures?

Logging enabled controller

Desktop Computers

Optional Server
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Engineering Related PMs (already available in commercial systems):

- Coordination
- Volume to Capacity
- Ped calls
- Etc.

Maintenance Related PMs (proposed):

- Detection not functioning properly
- Split Failures
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Darcy Bullock @darcybullock 26 Feb

Very cool implementation of #purduetlab and @JTRP1937 SPM by @EDIItraffic and @Acyclica
Detection not functioning:

- Patterns of vehicle arrivals at intersections are cyclical, repetitive and statistically similar
- High-resolution data files are easy to acquire and allow isolation of distinct detector channels
- Historic detector patterns can be used to inform an ‘expected’ pattern for any period for that detector
- Detector patterns can be treated similarly to communications signals, using same tools to identify statistically significant deviations
Kolmogorov-Smirnov Test:

Comparison of analysis week to average of previous weeks data, showing similarity of detection patterns.

Comparison of the cumulative probability distributions of two sets of data using the KS test.
Kolmogorov-Smirnov Test:

1. Calculate Sample Mean ($\mu$) and Sample Standard Deviation ($\sigma$).
2. Compute $|c-\mu| > 2\sigma$.
3. Perform the KS Test on the "past" and "current" samples.
4. Determine if $c$ is an anomaly (1) or not (0).

Output:
- 1 = anomaly
- 0 = no anomaly
Kolmogorov-Smirnov Test:

Detection rate of anomalies in detector data by duration and magnitude using the K-S test.
Kolmogorov-Smirnov Test: Sample Results

2PM to 7PM period
Kolmogorov-Smirnov Test:

- Analyzed by time period (same as daily patterns)
- Weekdays only
Kolmogorov-Smirnov Test:

- Works for both more or less than ‘normal’ activations

Channel 2 count and algorithm results

Channel 4 count and algorithm results

Channel 6 count and algorithm results

Channel 8 count and algorithm results
Kolmogorov-Smirnov Test:

Benefits of a statistical based detection error test:

• Works for intermittent errors
Kolmogorov-Smirnov Test:

Benefits of a statistical based detection error test:

- Works for intermittent errors
- Misalignment/obscurance errors
Kolmogorov-Smirnov Test:

Benefits of a statistical based detection error test:

- Works for intermittent errors
- Misalignment/obscurance errors
- And traditional device malfunctions

Exposed loop lead-in,
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Split Failures:

- When a specific movement (phase/split) at an intersection doesn’t have adequate time to clear out the entire queue of cars
Split Failures:

- Longitudinal view: look at an entire corridor in a single graph
- Good for finding what days or annual periods have problems
Split Failures: Longitudinal

Split Failures, 7/1/2015 to 12/31/2015
CR17 Corridor All Intersections

Split failures from all intersections stacked for each day

Weekends much less of a problem

Thanksgiving Holiday

0 Split-Failed Phase Occurrences

CR-10 @ CR-15
CR-17 @ Beck
CR-17 @ CR-10
CR-17 @ CR-18
CR-17 @ CR-20
CR-17 @ CR-28
CR-17 @ CR-38
CR-17 @ CR-4
CR-17 @ CR-6
CR-17 @ Middlebury St
CR-17 @ Missouri
CR-17 @ Rieth
CR-17 @ SR-119
CR-17 @ SR-120
CR-17 @ US-20N
CR-17 @ US-20S
CR-17 @ Verdant
(blank)
Split Failures: Longitudinal

Split Failures, 7/1/2015 to 12/31/2015
CR17 Corridor All Intersections

CR17/SR120

CR17/CR6
Split Failures: Intersection

Split Failures, 8/17/2015 to 8/28/2015
CR17/SR120 by lane

Can also focus on a single intersection and see split failures by lane
Split Failures: CR4

Split Failures, 7/1/2015 to 12/31/2015
CR17 Corridor All Intersections

Few split failures
Consistent split failures
Split Failures: CR4

Split Failures, 8/17/2015 to 8/28/2015
CR17 Corridor All Intersections

CR4
Split Failures: CR4

Split Failures, 8/17/2015 to 8/28/2015
CR4 by lane, by 15 min
Split Failures: CR4

Split Failures, 11/30/2015 to 12/11/2015
CR4 by lane, by 15 min
Why the huge jump in split failures from Aug to Nov?

- New traffic generator on this approach?
- Detection issue?
Split Failures: CR4

EB Camera blanks out during brighter daylight hours due to white balance issues.

Low light level, early morning

High light level, later in day
Split Failures: CR4

Split Failures, 1/1/2016 to 2/23/2016
CR17 Corridor All Intersections

Camera Issue Resolved
Split Failures: Mishawaka Example
Split Failures: Grape Rd.

Split Failures, 11/1/2015 to 12/31/2015
North Grape Rd Corridor

- Black Friday
- Christmas

Split-Failed Phase Occurrences


Grape @ Edison Lakes  Grape @ Indian Ridge  Grape @ University  Grape @ Douglas
Split Failures: Grape Rd.

Split Failures, 1/1/2016 to 3/4/2016
North Grape Rd Corridor

Saturday

Saturday

Split Failures: Grape Rd.

Shopping Areas

Grape @ Edison Lakes
Grape @ Indian Ridge
Grape @ University
Grape @ Douglas

(Blank)
Split Failures:

Predominately Shopping Area

Predominately Commuter Area
Split Failures: Grape/Univ

Very different shapes on Saturdays versus weekdays

Saturdays

Weekdays
Except for EB Thru, all other Thru lanes have few split failures. Reassign time to turn lanes?

Split Failures: Grape/Univ

Split Failures, 12/12/2015 and 12/19/2015
University/Grape by lane, by 15 min, Saturdays
Split Failures: Grape/Univ

Verify that split failure chart is correct?

Grape at University Video
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Signal problems are costly to users

No one has the budget to monitor 24/7

PMs can be done manually or automatically

Let the system tell you when there’s a problem

Alerts to detection problems

Split failure reports show bigger problem periods (longitudinal) or problem phases (individual intersections)