Generating Time Space Diagram Using Event-Based Traffic Data

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Organization of Presentation

1. Introduction – The SMART Signal System
2. Field Implementation
3. Visualization and Fine-tuning
4. Concluding Remarks
In the current practice, signal retiming is mostly based on data collected manually from the field. Due to the intensive labor cost involved, traffic signals are only re-timed every 2 ~ 5 years. Signal retiming is based on a fixed schedule, not based on the actual performance.
Evaluation for Signal Operation


- Management: D-
- Signal Operation at Individual Intersections: C
- Signal Operation in Coordinated Systems: D
- Signal Timing Practices: C-
- Traffic Monitoring and Data Collection: F
- Maintenance: C-

OVERALL: D

National Traffic Signal Report Card 2012

- Management: D
- Traffic Signal Operations: C
- Signal Timing Practices: C
- Traffic Monitoring and Data Collection: F
- Maintenance: C

OVERALL: D+

University of Minnesota Driven to Discover
SMART-Signal System

- SMART-Signal: Systematic Monitoring of Arterial Road Traffic Signals
  - An automatic and continuous data collection system
  - A performance measurement system on intersection queue length and arterial travel time, especially under congested traffic conditions
  - A performance fine tuning system for optimization of traffic signal parameters
Field Implementation (TS-1 cabinets)

In Moorhead, MN
Field Implementation (TS-2 cabinets)

- Power 9~30 VDC
- SDLC cable
- Ethernet cable

In Burnsville, MN
Offset Evaluation and Fine-tuning

- Traditionally, engineers largely rely on Synchro TS-Diagram.
- Field verification is done via probe vehicles, which is time consuming and labor intensive.
TS-Diagram Using Event-based Data

- Input: signal status & advance detector data

**TS-Diagram**

**Advance detector**

**Coordinated Direction**

<table>
<thead>
<tr>
<th>Detector occupation event</th>
<th>Detector ID</th>
<th>Occupied Duration(Sec)</th>
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<tbody>
<tr>
<td>Start Time of Detector “ON”</td>
<td>13</td>
<td>0.321</td>
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<tr>
<td></td>
<td>10</td>
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<td>1.369</td>
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<td></td>
<td>9</td>
<td>0.403</td>
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<table>
<thead>
<tr>
<th>Signal Event</th>
<th>Signal Status</th>
<th>Phase</th>
<th>Duration(Sec)</th>
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<tbody>
<tr>
<td>Start Time</td>
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<td></td>
<td></td>
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<tr>
<td>05:00:16.800</td>
<td>G</td>
<td>3</td>
<td>9.800</td>
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<tr>
<td>05:00:26.600</td>
<td>Y</td>
<td>3</td>
<td>4.000</td>
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<tr>
<td>05:00:33.100</td>
<td>G</td>
<td>4</td>
<td>10.300</td>
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<tr>
<td>05:00:43.400</td>
<td>Y</td>
<td>4</td>
<td>4.000</td>
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</table>
TS-Diagram Using Event Based Data

• Two steps to construct link-based TS-Diagram:
  – Step 1: Construct cyclic flow profile (CFP) at link entrance.
  – Step 2: Generate virtual vehicle trajectories based on CFP.
• Combine link-based TS-Diagram for arterial TS-Diagram
Field Example – TH13, PM Peak, on Jul 23, 2013
Lead-Lag Sequence

1: Lead-Lead

2: Lag-Lead

3: Lead-Lag

4: Lag-Lag

(Phase 1) Lead

(Phase 5) Lead

First green as offset reference

1

2

3

4

5

6

7

8

P1 — P2 — P3 — P4

P5 — P6 — P7 — P8

P1 — P2 — P3 — P4

P5 — P6 — P7 — P8

P1 — P2 — P3 — P4

P6 — P5 — P7 — P8

P2 — P1 — P3 — P4

P6 — P5 — P7 — P8

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P6 — P5 — P7 — P8

P2 — P1 — P3 — P4

P6 — P5 — P7 — P8

P2 — P1 — P3 — P4

P6 — P5 — P7 — P8
TH13, AM Peak, four weekdays
Int. Offset 7s to the left & Lead-Lead to Lead-Lag

Before (4 weekdays)

Int. Offset 4s to the left

After (2 weekdays)

Int. Offset 4s to the left

3193 ft

2521 ft

1838 ft

3027 ft
# MOE from SMART-Signal System

## Average Max Queue length (ft)

![Graph showing average max queue length before and after implementation](image)

<table>
<thead>
<tr>
<th>Average</th>
<th>Before</th>
<th>After</th>
<th>Abs. Change</th>
<th>Per. Change</th>
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</thead>
<tbody>
<tr>
<td>EB Vol. (vph)</td>
<td>1314</td>
<td>1310</td>
<td>-4</td>
<td>0%</td>
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<tr>
<td>EB Delay (sec)</td>
<td>32.4</td>
<td>27.8</td>
<td>-4.6</td>
<td>-14%</td>
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<tr>
<td>WB Vol. (vph)</td>
<td>1003</td>
<td>1007</td>
<td>4</td>
<td>0%</td>
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<tr>
<td>WB Delay (sec)</td>
<td>65.3</td>
<td>68</td>
<td>2.7</td>
<td>4%</td>
</tr>
<tr>
<td>Cycle Delay (Veh*Sec)</td>
<td>4607.6</td>
<td>4443.8</td>
<td>-163.8</td>
<td>-4%</td>
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Concluding Remarks

• We propose a practical procedure to construct the TS-Diagram for progression visualization and evaluation of signalized arterials.

• The proposed TS-Diagram was illustrated and validated with field examples. Reasonable agreements were found using detector and GPS data.

• An experiment was carried out to fine-tune the signal setting using the generated TS-Diagram. 4% reduction of total delays was achieved.
Future Researches

• To improve accuracy of TS-Diagram by incorporating data from adjacent intersections.

• To develop a systematic approach to facilitate automated optimization of offsets, lead-lag sequence, and green splits, using event based traffic data.

• To develop approaches for performance evaluation and fine-tuning of cycle length and time-of-day transition schedules.
Thank you!