ARE ADAPTIVE SIGNAL CONTROL SYSTEMS A SOLUTION TO GROWING URBAN CONGESTION?

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Outline

- Overview of adaptive signal control systems
- Before-after evaluation studies
- SMRT developed at UNR for signal timing
- Final thoughts
Signal Control Systems in the U.S.

- About 300,000 signals in the U.S.
- Conventional systems (95%+)
  - Centralized
  - Closed-loop
- Adaptive systems
  - Various vendor systems are emerging
  - Not yet widely accepted by agencies
Adaptive Systems in the U.S.
InSync by Rhythm Engineering

AS OF MAY 2013

Scheduled
Deployed
Adaptive System Performance

- Before-after studies

- A valid comparison study must possess:
  - Extensive data: travel time runs, delays, queues
  - A broad range of flow conditions: normal, directional, special events, preemption
  - *Truly optimized conventional TOD timing plans*
  - What if a comparison is made against bad TOD timing plans?
What is Considered as a Good Timing Plan

- **Ideal conditions**
  - No extensive over-capacity
  - Spacing is adequate (not too short)
  - Protected LTs which allows lead/lag phasing

- **Rule of thumb**
  - No more than 1 stop for every 5 signals
Adaptive vs. Conventional

Table 7 – Average Number of Stops for Grant Road Analysis

<table>
<thead>
<tr>
<th></th>
<th>SB</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>% change</td>
<td>Before</td>
<td>After</td>
<td>% change</td>
<td>Before</td>
<td>After</td>
<td>% change</td>
<td></td>
</tr>
<tr>
<td>AM</td>
<td>3.3</td>
<td>1.5</td>
<td>-55%</td>
<td>3.2</td>
<td>2.7</td>
<td>-16%</td>
<td>3.25</td>
<td>2.1</td>
<td>-35%</td>
<td></td>
</tr>
<tr>
<td>PM</td>
<td>2.7</td>
<td>2.3</td>
<td>-15%</td>
<td>2.8</td>
<td>2.8</td>
<td>0%</td>
<td>2.75</td>
<td>2.55</td>
<td>-7%</td>
<td></td>
</tr>
</tbody>
</table>

Table 1 – Existing Operations, Cycle Lengths and Time of Day

<table>
<thead>
<tr>
<th>Intersection</th>
<th>AM Peak</th>
<th>Time of Day</th>
<th>AM Off-Peak</th>
<th>Time of Day</th>
<th>Mid-Day Peak</th>
<th>Time of Day</th>
<th>PM Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bentley Sq</td>
<td>140</td>
<td>7:40-9:30A Free</td>
<td>9:30-11:30A</td>
<td>120</td>
<td>11:30A-2:30P</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>Phyllis Ave/Martens Dr</td>
<td>140</td>
<td>7:40-9:30A Free</td>
<td>9:30-11:30A</td>
<td>120</td>
<td>11:30A-2:30P</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>Cuesta Dr</td>
<td>140</td>
<td>7:40-9:30A Free</td>
<td>9:30-11:30A</td>
<td>120</td>
<td>11:30A-2:30P</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>North Dr/Eunice Ave</td>
<td>120</td>
<td>7:00-9:30A Free</td>
<td>9:30-11:30A</td>
<td>120</td>
<td>11:30A-2:30P</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>South Dr</td>
<td>120</td>
<td>7:00-9:30A Free</td>
<td>9:30-11:30A</td>
<td>100</td>
<td>11:30A-2:30P</td>
<td>116</td>
<td></td>
</tr>
<tr>
<td>Covington Rd</td>
<td>120</td>
<td>7:00-9:30A Free</td>
<td>9:30-11:30A</td>
<td>100</td>
<td>11:30A-2:30P</td>
<td>116</td>
<td></td>
</tr>
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<td>100</td>
<td>11:30A-2:30P</td>
<td>116</td>
<td></td>
</tr>
</tbody>
</table>

1 Period Cycle Length (seconds)
# Bollinger Canyon Road

## Eastbound

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Test Period</th>
<th>Average Travel Time (sec)</th>
<th>Average Number of Stops (No.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM Peak (7-9AM)</td>
<td>Before</td>
<td>86.7</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td>After</td>
<td>64.0</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>% Diff.</td>
<td>-26.2%</td>
<td>-81.8%</td>
</tr>
<tr>
<td>AM Off-Peak (9-11AM)</td>
<td>Before</td>
<td>70.6</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>After</td>
<td>64.5</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>% Diff.</td>
<td>-8.6%</td>
<td>-14.3%</td>
</tr>
<tr>
<td>Midday Peak (11:30AM - 1:30PM)</td>
<td>Before</td>
<td>114.1</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>After</td>
<td>71.8</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>% Diff.</td>
<td>-37.1%</td>
<td>-53.3%</td>
</tr>
<tr>
<td>PM Peak (4:30-6:30PM)</td>
<td>Before</td>
<td>79.5</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>After</td>
<td>83.9</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>% Diff.</td>
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<td>0.0%</td>
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</tr>
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<td></td>
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<td>79.5</td>
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<tr>
<td></td>
<td>After</td>
<td>73.7</td>
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<tr>
<td></td>
<td>After</td>
<td>72.5</td>
<td>0.6</td>
</tr>
<tr>
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</table>
Adaptive vs. Conventional

Diagram showing comparative timelines and traffic signals for Adaptive and Conventional methods at various cross streets and approaches.
Adaptive vs. Conventional

College Avenue

N. Dutton Ave
Cleveland Ave
US 101 SB ramp
US 101 NB ramp
Morgan Ave
Mendocino Ave
Humboldt Ave
E St / King St
Brookwood Ave
North St
## Adaptive vs. Conventional

### Number of Stops

<table>
<thead>
<tr>
<th>Corridor – Direction</th>
<th>Period</th>
<th>Average # Stops Before</th>
<th>Average # Stops After</th>
</tr>
</thead>
<tbody>
<tr>
<td>College EB</td>
<td>6:00-7:20</td>
<td>3</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>7:20-9:10</td>
<td>3.5</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>9:10-11:45</td>
<td>4.5</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>11:45-14:45</td>
<td>4.5</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>14:45-18:00</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>18:00-19:00</td>
<td>5.5</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>19:00-20:30</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>College WB</td>
<td>6:00-7:20</td>
<td>3.5</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>7:20-9:10</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>9:10-11:45</td>
<td>4</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>11:45-14:45</td>
<td>11</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>14:45-18:00</td>
<td>12</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>18:00-19:00</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>19:00-20:30</td>
<td>5.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>
Case Study
Boulder Highway, Las Vegas

US 95 SB
US 95 NB
Desert Inn
Flamingo & Nellis
Indios
Nellis
Harmon
Tropicana
Boulder Hwy
Before Case - Time of Day Coordination - AM Peak - SB Direction

- Tuesday
- Wednesday
- Thursday
- Friday
- Speed Limit

Intersections:
- Tropicana
- Harmon
- Nellis
- Flamingo
- Indios
- Desert Inn
- US-95 NB
- US-95 SB

Time (Sec)

After Case - SCATS Adaptive System - AM Peak

- Monday
- Tuesday
- Wednesday
- Thursday
- Friday
- Speed Limit

Intersections:
- Tropicana
- Harmon
- Nellis
- Flamingo
- Indios
- Desert Inn
- US-95 NB
- US-95 SB

Time (Sec)

Before Case:
- 3 runs without a stop

After Case:
- At least 1 stop

Stopped Bus
**Before Case - Time of Day Coordination AM Peak - NB Direction**

- US-95 SB
- US-95 NB
- Desert Inn
- Indios
- Flamingo
- Nellis
- Harmon
- Tropicana

**Time (Sec)**

- 0
- 100
- 200
- 300
- 400
- 500
- 600
- 700
- 800

**Before** – Time of Day Coordination
1 short stop

**After Case - SCATS Adaptive System - AM Peak - NB Direction**

- US-95 SB
- US-95 NB
- Desert Inn
- Indios
- Flamingo
- Nellis
- Harmon
- Tropicana

**Time (Sec)**

- 0
- 100
- 200
- 300
- 400
- 500
- 600
- 700
- 800

**After** – Adaptive
At least 1 stop
Before – Time of Day Coordination - PM Peak - SB Direction

- Tuesday
- Wednesday
- Friday
- Speed Limit

Intersections:
- Tropicana
- Harmon
- Nellis
- Flamingo
- Indios
- Desert Inn
- US-95 NB
- US-95 SB

Before Case

Time (Sec) 0 100 200 300 400 500 600 700 800

After Case - SCATS Adaptive System - PM Peak - SB Direction

- Monday
- Tuesday
- Wednesday
- Friday
- Speed Limit

Intersections:
- Tropicana
- Harmon
- Nellis
- Flamingo
- Indios
- Desert Inn
- US-95 NB
- US-95 SB

After – Adaptive
Before – Time of Day Coordination - PMPeak - NB Direction

After Case - SCATS Adaptive System - PM Peak - NB Direction
Preemption

Before – Time of Day

After – Adaptive
How to Achieve a True Optimized Timing Plan
Real-world Issues

- Variable speeds
- Early releases
- Wrong offset reference
  - Start or end of coordinated phases
  - TS2-1\textsuperscript{st} Green or First Ring
- Signal out of coordination
  - Preemption
  - Pedestrian
  - Loss communication
- Clock time
Before-After

After  Total = 4’04”
       Stop = 1

Before Total = 6’15”
       Stop = 4
SMRT
Signal Management and Re-timing Tool
Before Timing
Final Thoughts

- Adaptive is good in concept, but the technology/algorithm is still evolving

Misconceptions
- Low maintenance, no re-timing effort
- Better for oversaturated conditions
- Retiming vs. fine-tuning

Limitations
- Unconventional intersections, phasing sequence optimization, Link-based
My Words

Signal timing is more of an art than engineering or science. Therefore, artists (engineers) can never be replaced by machines (adaptive).