Adaptive Traffic Control Systems: Field And Microsimulation

Mid-Continent Transportation Research Symposium

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Presentation Outline

- Importance of Traffic Signal Control
  - Signal Timing Parameters and Ageing
- Research Problem
  - Goal and Objectives
- Field Evaluations
  - SCATSs Field Evaluation
  - Before/After vs. Off/On
- Microsimulation Evaluations
  - SCOOT and SCATS Comparison
- Field and Microsimulation Equivalence
- Summary and Future Research
Traffic in Our Future

- **Growth: Traffic vs Infrastructure**
  - 1970s - 1 trillion VMT
  - 2007 – 3 trillion VMT

- **Congestion**
  - Longer Trip times
  - Longer Peak Periods
  - Less Reliability

- **Environment**
  - Stricter Standards vs Longer Idle Times
Traffic Signal Control

- Provides Safe Passage to Roadway Users
  - Vehicles
  - Transit
  - Pedestrians

- Allocates Directional Right-of-Way via Signal Timing Parameters
  - Cycle length
  - Splits
  - Offsets
  - Phases/Sequencing
Ageing of Signal Timing Plans

- Parameters Optimized for Current Demand and Distribution
  - Pretimed Regime - Rigid
  - Actuated Regime
  - Adaptive Regime - Flexible
Effects of Ageing

- Inefficient Traffic Flow
  - Poor Performance (Measures)
    - Travel Time
    - Travel Delay
    - Stopped Delay
    - Number of Stops
    - Fuel Consumption
    - Carbon Emissions

- Required Maintenance
  - Agency Resources
Ageing as a Problem

- There are 350,000 traffic signals in the United States
  - 75% could operate more efficiently
- National Traffic Signal Report Card survey of 417 operating agencies
  - 38% do not review timings at least every 3 years
  - 49% lack resources to monitor/manage traffic on a regular basis
Ageing-Specific Research

- Ageing of Fixed-Time Traffic Signal Plans
  - Bell, M.C. (1985)*

- Assessing Deterioration of Pretimed, Actuated-Coordinated, and SCOOT Control Regimes in Simulation Environment

* Also: Bell, M.C., and Bretherton, R.D. (1986)
Missing Links in Ageing Research

- Assessment of Conventional and Adaptive Traffic Control Evaluations in the Field
  - Is There A Preferred Technique?
- Investigation of Multiple ATCSs on a Single Microsimulation Network
  - Are All ATCSs The Same?
- Equivalence of Field and Microsimulation ATCS Evaluations
  - Can One Be A Substitute For The Other?
Problem: Traffic Congestion Due to Ageing of (Conventional) Traffic Control Systems

- Can ATCSs Minimize Performance Impacts From Ageing?

**Objectives**

1. Determine Field Performance Benefits of ATCSs
2. Compare ATCS Field Evaluation Techniques
3. Evaluate Performance of ATCSs through Microsimulation
4. Analyze Implementations of Multiple ATCSs
5. Comparatively Assess Equivalence of Field and Microsimulation ATCS Evaluations
Compare ATCSs to Conventional Control

Perform Field Evaluation
- Compare Before and After Studies
- Determine Equivalence of Before and Off Studies

Perform Microsimulation Evaluation
- Compare Off and On Studies
- Compare Systems in Real-World Network
- Compare Systems in Theoretical Network

Determine Equivalence of Field and Microsimulation Evaluations

Research Methodology
Objective 1 - Determine Field Performance Benefits of ATCSs

- First Studied in 1982
  - Very Few Other Field Studies Since
- Off/On Technique
  - Flexi vs Master Link
- Network: Park City
  - ATCS – 14 Intersections
    - SCATS Adaptive
Travel Time

Average Time, s

AM - NB
AM - SB
PM - NB
PM - SB
MD - NB
MD - SB

Period - Direction

SCATS Off
SCATS On
Intersection Stopped Delay

Average Stopped Delay (sec/veh)

- SCATS Off
- SCATS On

Left
- Main Road
- Through

SCATS Off
- Left

SCATS On
- Side Road
- Through
SCATS and TOD Cycle Lengths

September 18, 2007

Cycle Length (seconds)

Nominal Cycle Length

Plan 2 - 82 sec
Plan 3 - 86 sec
Plan 4 - 96 sec
Plan 5 - 128 sec
Plan 2 - 82 sec

Split Plan

Nominal Cycle Length | A phase split | B phase split | C phase split | D phase split | Link Plan
--- | --- | --- | --- | --- | ---
--- | --- | --- | --- | --- | ---
0 | 1 | 2 | 3 | 4 | 5
6 | 7 | 8 | 9 | 10 | 11
12 | 13 | 14 | 15 | 16 | 17
18 | 19 | 20 | 21 | 22 | 23
24
Objective 1 - Conclusions

- SCATS improved performance:
  - Travel times were reduced
    - Lowered by 7.6, 3.9 & 1.9% for AM, PM & MD periods
  - Number of stops were reduced
    - Lowered by an average of one-half stop for all time periods and directions
  - Travel time stopped delay was reduced
    - Lowered by one-half minute on the weekend to one full minute during the weekday
  - Intersection stopped delay for through movements on both main and side roads were reduced by 2 seconds.

- Overall: SCATS ATCS Provides Superior Field Performance over Conventional Traffic Control
Objective 2 - Compare ATCS Field Evaluation Techniques

- Unique Comparison: Before/After vs Off/On Study
  - Study Techniques Unbiased towards Regimes

- Network: Park City
  - Before – 12 Intersections
    - Actuated-Coordinated
  - After/On – 14 Intersections
    - Adaptive
Comparison of Over 600 Signal Timing Parameters
Travel Time Performance

![Travel Time Performance Chart]

- **Before SCATS**, **SCATS Off**, **SCATS On**
Intersection Stopped Delay

Average Stopped Delay (sec/veh)

- Main Street Through
- Main Street Left
- Side Street Through
- Side Street Left

Before SCATS, SCATS Off, SCATS On
Objective 2 - Conclusions

- Outputs from before/on and off/on studies found that results behaved consistently 62.5% of the time
  - SCATS is slightly better than conventional control when assessed through both before/on and off/on approaches
  - When assessed only through the off/on approach, SCATS results were more favorable

- Numerous changes to the network, volumes or signal timing parameters limit the substitutional value of ‘before’ and ‘off’ evaluations

- Overall: Off/On Studies May Be A Substitute For Before/After ATCS Studies
Objective 3 - Evaluate Performance of ATCSs through Microsimulation

- First Comparison of Multiple ATCSs on a Single Validated Network
  - Microsimulation Network: Park City
    - Conventional Control - EILS
    - SCOOT Adaptive - HILS/EILS
    - SCATS Adaptive – SILS/EILS
  - Variable Traffic Demand
    - ± 2% and ± 25% of traffic flows
  - Multiple Simulation Runs
    - 300 real-time SCOOT-VISSIM simulations
    - 30 simulations for SCATS and Conventional control
Lower Variability Traffic Demand

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>Coord.- actuat.</th>
<th>SCATS</th>
<th>SCOOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Delay (hours)</td>
<td>418.6</td>
<td>355.8</td>
<td>361.3</td>
</tr>
<tr>
<td>Number of Stops</td>
<td>60940</td>
<td>46766</td>
<td>55879</td>
</tr>
<tr>
<td>Stopped Delay/Veh. (s)</td>
<td>41.5</td>
<td>32.6</td>
<td>32.5</td>
</tr>
<tr>
<td>Throughput (vehicles)</td>
<td>18912</td>
<td>18948</td>
<td>18929</td>
</tr>
</tbody>
</table>
Objective 3 - Conclusions

- Both SCOOT and SCATS deliver significant benefits over coordinated-actuated
  - Delay, journey time average stopped delay, traffic throughput, and stops reduced by at least 10%
- SCATS has fewer stops than SCOOT
  - Other measures are similar for SCOOT and SCATS
- Experiments with lower and higher variability in traffic demand do not show any difference
  - Both SCOOT and SCATS can readily handle small fluctuations in traffic demand.
- Overall: ATCSs Provide Superior Performance in Microsimulation over Conventional Signal Control
Objective 4 - Analyze Implementations of Multiple ATCSs

- Explanation of effectiveness of SCOOT and SCATS operations at a microscopic level
- Park City Network – Two segments
  - Favoring performance for each ATCS
- Analysis of Signal Timing Adjustments
  - Responding to changes in traffic flows
  - Impacts on performance measures
SCOOT and SCATS: Offsets and Quality of Progression – Segment 1
SCOOT and SCATS: Cycle Lengths, Delay and Throughputs – Segment 2

The diagram compares the cycle lengths, delays, and throughputs between SCOOT and SCATS for Segment 2. The graphs show fluctuations over time, with markers indicating when one system is better than the other. The key points are:

- **Cycle Lengths**: SCATS generally has longer cycle lengths than SCOOT.
- **Delay**: SCOOT has higher delays, especially at the beginning.
- **Throughput**: SCATS outperforms SCOOT in terms of throughput throughout the observed period.

Overall, the diagram illustrates that SCATS performs better in terms of cycle lengths and throughputs compared to SCOOT, with occasional instances where SCOOT is better, especially in initial phases.
Objective 4 - Conclusions

- Both systems cope with predominantly under-saturated traffic demand.
- SCATS cycle lengths seem more responsive while SCOOT tends to keep cycle lengths at lower levels for longer time.
- SCATS offsets provide better progression which results in fewer stops.
- Overall: Both ATCSs Deliver Similar Performance
Objective 5 - Comparatively Assess Equivalence of Field and Microsimulation ATCS Evaluations

- First comparative assessment of ATCS network evaluations
- Park City Networks – Field and Microsimulation
  - Before/After Study
    - 12 Intersection Calibration and Validation
  - Field Off/On Study
    - 14 Intersection Re-Validation
Comparing Field and Microsimulation Performance

**STEP 1:** Collect Field Data

**STEP 2:** Build Model

**STEP 3:** Calibrate Model

**STEP 4:** Validate Model

**STEP 5:** Re-build Model

**STEP 6:** Revalidate Model

**STEP 7:** Run ‘Off’ & ‘On’ Cases

**STEP 8:** Compare Results from Model & Field

Report Findings

Model = Field Sept '07?

Yes

No

Model = Field Aug '05?

Yes

No

Model = Field Aug '05?
Field and Model: SCATS On and SCATS Off Travel Times
Northbound

Field Off
Microsimulation Off
Field On
Microsimulation On

Intersection Segments
Travel Time (sec)
Results of Statistical Testing

<table>
<thead>
<tr>
<th>Travel Time</th>
<th>Field</th>
<th>Microsimulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCATS Off</td>
<td>SCATS On</td>
<td>SCATS Off</td>
</tr>
<tr>
<td>Avg</td>
<td>809.1</td>
<td>781.3</td>
</tr>
<tr>
<td>StDev</td>
<td>89.9</td>
<td>73.9</td>
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<tr>
<td>Samples</td>
<td>44</td>
<td>60</td>
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<tr>
<td>Number of Stops</td>
<td>Avg</td>
<td>5.5</td>
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<tr>
<td>StDev</td>
<td>2.4</td>
<td>2.0</td>
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<tr>
<td>Samples</td>
<td>44</td>
<td>60</td>
</tr>
</tbody>
</table>
Objective 5 - Conclusions

- Microsimulation successfully replicated field performances of an ATCS
  - More successful results were achieved for travel times than for stops
  - SCATS On data was more supportive than Before SCATS

- Overall: Microsimulation Provides Equivalent ATCS Field Performance
Research Goal - Summary

- ATCS Performance Benefits
  - SCATS Provides Superior Field Performance over Conventional Traffic Control
  - Off/On Studies May Be A Substitute For Before/After Studies
  - In Microsimulation ATCSs Provide Superior Performance over Conventional Signal Control
  - SCOOT and SCATS Deliver Similar Performance
  - Microsimulation Provides Equivalent ATCS Field Performance