Adaptive Signal Control Technology Research in Illinois

Kyle Armstrong, Ray Benekohal, Xueying Liu
Overview

• ASCT
• ASCT Research
• Study Phases
  • Before Study
  • SynchroGreen Implementation
  • After Study
  • Future Tasks
What is Adaptive Signal Control Technology (ASCT)?

• Continuously adjusts traffic signal timings to accommodate real-time changes in traffic patterns and to improve traffic flow

• Several manufacturers and products with different methodologies for adjusting timings

• Some systems may only require software upgrades while others may require additional controller and detection hardware

• Included in first round FHWA’s Every Day Counts Initiative which helps promote and advance implementation of proven technologies
Benefits of ASCT

• Improves travel times through coordinated signal system

• Allows more flexibility and adjustments for sudden changes in traffic patterns.

• Reduces number of vehicle stops and wait times leading to reduced fuel consumption

• Reduced number of crashes?
Purpose of ASCT research

- Determine if there is a reduction in crashes due to ASCT implementation (rear-end crashes & left turn crashes)
- Develop a Crash Modification Factor (CMF) for ASCT implementation
- Measure improvements in traffic flow and efficiency
- Implementation site can be used as a test bed for future ASCT training and research
Purpose of ASCT Research

- Testimonials and information from manufacturer websites typically show improved traffic flow and efficiency benefits.
- There appears to be minimal research and information regarding potential safety benefits of ASCT.
- Reduction in stops should help reduce rear-end crashes.
- Flexibility in adjusting individual phase times particularly for left turning traffic could reduce angle crashes.
Research

Quick Research
• Gathered crash and cost data from agencies outside Illinois
• Data acquired through user surveys

Full Research
• Installed ASCT system along Neil St. in Champaign
• Gathering before and after efficiency and crash data
• Develop CMF for ASCT implementation
Quick Research

• Wanted to see which agencies had implemented ASCT and if they had performed post-implementation studies

• Completed January 2013 with over 20 agencies responding

• Average cost per intersection, $38k

• Data showed reduction, but very limited sample size

• Enough to move forward with full implementation and study
Full Research - Overview

• Initially 3-year project beginning in 2013

• Phase 1 – Select test site, perform systems engineering analysis, collect pre-implementation data

• Phase 2 – Purchase and install ASCT system, post-implementation data, develop benefit-cost and CMF information
Full Research – Phase I

- Selection of Test Site
  - No recent significant safety improvements
  - Recently studied for coordination
  - High variance of traffic volumes

- Selected Neil St. corridor in Champaign

- Acquired pre-installation data

- Performed systems engineering analysis based on requirements and needs for the Neil St. system
Full Research – Systems Engineering Analysis and Selection/Procurement

• Method to outline and determine proposed ASCT system capabilities

• Very technical analysis. Signal personnel should be involved

• TRP developed requirements and scored ASCT vendor proposals

• State procurement process was difficult
Full Research – Phase 2, ASCT System

- Trafficware SynchroGreen system selected
- Installed April 2015 with full acceptance November 2015
- System required video detection installation
- Allowed vendor to adjust detection and timing programs
Full Research – Phase 2

• Primary goal is to develop a Crash Modification Factor in accordance with recommendations from NCHRP 20-7(314)

• Consider including in Crash Modification Factor Clearinghouse and Highway Safety Manual
TRP Members

Mike Hine (FHWA)          Gary Sims (IDOT D5)
Dean Mentjes (FHWA)       David Burkybile (IDOT D5)
Chris Dipalma (FHWA)      Mike Irwin (IDOT D6)
Kevin Burke (BLRS)        Jon Nelson (Lake Co.)
Tom Winkelman (BLRS)      Yogesh Gautam (IDOT Ops)
Irene Soria (BSE)         Glen Berger, City of Champaign
Tim Sheehan (BSE)         
Kristen Micheff (IDOT D1) 
Eric Howald (IDOT D4)     

Before Data Collection

• 12 days of data collected using video recorders for the six intersections (option to choose the best day) in fall 2013

• Data collection periods:
  - Morning 7:00 am – 9:00 am
  - Noon 10:30 am – 1:30 pm
  - Afternoon 4:00 pm – 6:00 pm

• 6 days of data collection for travel time using a GPS unit
Before Data Reduction

• Data reduction periods:
  - Morning 7:10 am – 8:40 am
  - Noon and off peak 10:40 am – 1:15 pm
  - Afternoon 4:40 pm – 6:00 pm

• Data reduction items:
  - Volume
  - Stopped delay
  - Queue length
  - Saturation flow rate
  - Signal timing (phase, cycle, green time)
  - Travel time
Peak Hours

- Volumes obtained manually from videos
- Peak hours determined based on volumes at major intersections: Stadium, Kirby, St. Mary, Windsor

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morning Peak</td>
<td>7:30 am – 8:30 am</td>
</tr>
<tr>
<td>Noon Peak</td>
<td>12:10 pm – 1:10 pm</td>
</tr>
<tr>
<td>Afternoon Peak</td>
<td>4:40 pm – 5:40 pm</td>
</tr>
<tr>
<td>Off Peak selected</td>
<td>10:40 am – 11:40 am</td>
</tr>
</tbody>
</table>
Stopped Delay

- Used HCM procedure for field measurement of intersection stopped delay

- **Extensive data reduction efforts for delay:**
  - 4 analysis periods
  - 6 intersections
    - 4 approaches at each intersection (3 at Devonshire)
      - For 3 movements on each approach (left, through, and right)
        - In every 15 seconds, determined:
          - No. of vehicles stopped
          - No. of vehicles that went through
          - No. of stopped vehicles at the end of 15 sec period

Extracted data from about 300 hours of video
Each hour delay data took 3-4 hours to reduce
Queue Length

- Queue lengths were found from the video for thru movements at 6 intersections for 4 time periods

- At the beginning of green phases of each cycle:
  - Recorded vehicles stopped in queue
  - Recorded vehicles that joined end of queue

- Each hour queue data took 2-3 hours to reduce

- Queue length comparison results will be presented in the Poster Session today
Saturation Flow Rate

- Found using HCM 2010 procedure

* All saturation flow rates given in passenger car per hour of green per lane (pcphgpl)
Signal Timing

• Videos used to record the frequency and duration of the signal phases:
  – For AM, Noon, and PM peak hours (off peak is same as noon peak)
    • For each intersection
    • For each approach

• Useful to analyze the system behavior and replicate conditions in HCM
Arrival Type (AT)

- AT 2, 3, and 4 for Neil St thru movements based on field data
  - AT were estimated based on the proportion of vehicle stopped, and by viewing of video of when platoon arrived during the cycle
  - On Major app AT was 4, except NB at Kirby (PM and Noon) and SB at St Mary’s (AM) which had AT of 2.

- For streets crossing Neil, and for left-turn movements from Neil, arrival type 3 was assumed.
Travel Time

- Recorded GPS coordinates, speed and time every second

- It shows variations from
- Run to run
- Segment to segment
- Travel time for each segment or the entire corridor

![Graph: NB Morning Peak, Nov 18](image)
Crash Data

- Obtained crash data of 2011-2013 from IDOT
- Contains 165 records of crashes in the study area (at intersection = 95 and on links = 70)
- Will use 2011-2014 data for before conditions
- CMF (crash modification factor) will be developed using before and after crash data
## Crash Data: Preliminary Analysis

<table>
<thead>
<tr>
<th>Intersection</th>
<th>Most Frequent Intersection Crash Type (2011-13)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stadium &amp; Neil</td>
<td>Turning (6 out of 11)</td>
</tr>
<tr>
<td>Kirby &amp; Neil</td>
<td>Rear End (22 out of 37)</td>
</tr>
<tr>
<td>St Mary's &amp; Neil</td>
<td>Angle &amp; Rear End (2 out of 6)</td>
</tr>
<tr>
<td>Devonshire &amp; Neil</td>
<td>Rear End (3 out of 3)</td>
</tr>
<tr>
<td>Knollwood &amp; Neil</td>
<td>Rear End (1 out of 1)</td>
</tr>
<tr>
<td>Windsor &amp; Neil</td>
<td>Turning (17 out of 32)</td>
</tr>
</tbody>
</table>
SynchroGreen Implementation

- System installation started: Apr 27, 2015
- System fine-tuning/software update continued: May 4-8, 2015
- Further Improvement at Knollwood: May 16-18, 2015
- 4-day SynchroGreen training: June 11-14, 2015
- Software and settings update: July, 2015
- Preliminary feedback on system performance sent to vendor: Aug 11, 2015
- Further feedback and requests was sent to vendor: Oct, 21, 2015
- Final adjustments completed by vendor: Nov 10, 2015
- System was accepted: Nov 10, 2015
Preliminary Feedback on August 11

- Had 25 pages reporting on system’s performance:
  - Travel time comparison
  - Speed profile on the corridor
  - Volume counts (manually reduced vs. system)
  - Observed queue lengths
  - Observed cycle lengths
In “Before” conditions, no plaza at Neil & Devonshire

- After conditions will have traffic from the plaza at the corner of Neil St & Devonshire
- Grocery store, hardware store, gas station, hotel and restaurants etc. that will generate additional traffic
Oct 2016
Development at Neil St & Devonshire

- Right turning-lane added at the intersection
- Need to quantify effects of volume increases due to the development
- Developed a methodology to quantify it using field and HCM results
Capacity Analysis

• Highway Capacity Software (HCS) 2010 was used to perform capacity analysis and analyze effects of volume changes
  – Capacity analyses was performed for each time period for all 6 intersections using data for before ASCT

• Separate HCS file for each intersection were prepared rather than single arterial file
  – Half-cycle not possible in HCS arterial analysis
Before Delay Study

• Stopped delay comparison: HCM vs. Field-measured
  – HCM will be used to estimate
    • the delay increase due to shopping traffic
  – Data
    • Data for “Before” condition; for all thru lanes (used EB left at Devonshire)
    • RTOR traffic on Stadium and St. Mary’s are considered
  – HCM estimates:
    • Multi-period analysis (4 periods of 15 minutes)
  – Statistical analysis
    • One-sample t-test, with 90% confidence
Before Delay Study (Cont.)

• Delay comparison results
  – 84 cases [4 time periods *(12 major app + 9 minor app)]
  
  – HCM estimates were not accurate in 58.3% of cases (49 out of 84)
    • Overestimation: in 73.5% cases (36 out of 49)
      o all at typical 4-legged intersections
    
    • Underestimation: in 26.5% cases (13 out of 49)
      o 10 at atypical intersections (Devonshire and Knollwood)
      o 3 at typical intersections
Before Delay Study (Cont.)

- Delay comparison results
  - Significant discrepancies for typical intersections- major street

![Typical Intersections, Major St](chart.png)
Before Delay Study (Cont.)

- Delay comparison results
  - Significant discrepancies for typical intersections - minor streets

![Typical Intersections, Minor Sts](chart.png)
After Data Collection

• Collected in Dec 2015 using system cameras installed at the intersections
  
  – Live video feeds recorded during off-peak and three peak hours

• Travel time data were collected in late March and early April, 2016
Data reduction status for after conditions

• Volume and delay data were reduced for all intersections, except
  – Kirby Noon Peak & PM and Windsor Off Peak, Noon Peak & PM

• Queue lengths for all intersections
  – To be started
Future Tasks

1. Regularly monitoring the system to ensure its working

2. After data reduction is completed, compute
   - Delay and queue from field data and HCM
   - Do analysis to account for the real estate development at Neil St & Devonshire

3. Collect “after conditions” field data in 2016
   - In early November and early December, During special events

4. Compare MOE for before and after conditions (2013, 2015 and 2016 data)
   - Delay, Queue length, Travel time

5. Analyze crash data

6. Develop CMIF for safety performance evaluation
Thanks!

Questions?

Kyle Armstrong  (Kyle.Armstrong@illinois.gov)
Ray Benekohal   (rbenekeh@illinois.edu)
Xueying Liu     (xliu158@illinois.edu)