Roadmap to Successful Deployment of Adaptive Systems

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Hampton Roads Transportation Operation Subcommittee
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Adaptive System Overview

- Why is it needed?
- What does it do?
- Where does it work better?
- Integration with current infrastructure, signal systems and management centers and other technologies
- Required Hardware/Software
- Installation & maintenance
- Training
- Overall expected benefits
- Other aspects?
Why Do We Need Adaptive Control?

- Growing congestion in urban areas
- Lack of infrastructure expansion capabilities to further expand traffic networks
- Responding to traffic surges and unpredictable demands
  - Handling daily and weekly fluctuations in traffic flows
  - Incident Response - Managing signal timing along corridors during diversion from freeways onto the parallel arterials
- Outdated signal timing plans
  - Cost of signal retiming
  - Changes in traffic demand/pattern
Expected Benefits

- Mitigate effects of the capacity reduction
- Dynamically manage recurring and non-recurring congestion based on prevailing traffic conditions
- Continuously adjust signal timing parameters (e.g., splits, cycle and offset)
- Reduce stops/delay
- Reduce fuel consumption
- Reduces emissions and improve Air Quality
Cycle Length Adaptability

Mill Plain Blvd / 104th-105th Ave

- Pretimed Cycle Length
- OPAC Cycle Length
- Vehicle Counts
- Incident Occurs

Time
Adaptive System Design

- Fully Adaptive vs. Partially Adaptive
- Centralized vs. Distributed
- Proactive vs. Reactive

*Traffic Responsive (TRSP) is not an adaptive system*
Where it works?

- Some adaptive systems are suitable for grid works (requires ability to provide balanced traffic control)
- Others are known for their ability to adjust signal timings on corridor-type networks.
Adaptive Traffic Signal Control Processes

Offset Optimizer — Split Optimizer — Cycle Optimizer

Offset weights — Split weights — Cycle weights

Platoon modeling

Intersection control

Traffic Engineer

Expert Rules

Volume

Occupancy

A or B

A + B
Installation/Maintenance

- Varies based on deployed adaptive algorithm
- Initial cost of detectorization
- Communication infrastructure
- Initial calibration and fine tuning
- Training
- Maintenance cost (maintaining detector operation)
Example - OPAC Adaptive Control

- Optimized Policies for Adaptive Control (OPAC)
- A fully adaptive, distributed real time traffic control system
- Continuously adjusts signal timing parameters (e.g., splits, cycle and offset)
- Signal timing optimization designed to minimize total intersection delay and/or stops
- Support for phase skipping in the absence of demand
- Configurable to respond to changes in left turn lead/ lag phasing by time of day
Control Layers in OPAC

- **Network Synchronization Layer**
  - (cycle optimization)

- **Coordination Layer**
  - (offsets optimization)

- **Local Control Layer**
  - (splits optimization)

- Split – Distributed to each intersection
- Offset – Distributed to each intersection
- Cycle Length – Section-wide; calculated at central
  - Background cycle (Dominant intersections)
  - Local adjustments at intersection level
OPAC Hardware Configuration

- Advanced Traffic Controllers
- OPAC Single Board Computer (local)
- Upstream Advance Detectors

Cabinet

Traffic Signal Controller: Type 2070 or NEMA (TS1 / TS2)

Single Board Computer (Linux OS) running OPAC software

Stop Bar

Adaptive Detector

Phase Detector

Adaptive Detector

Phase Detector

Detected Data

Force offs & Holds

8-12 secs travel time at prevailing speeds
Integration with Traffic Management System
OPAC Deployments

- Several field tests during 1990-2003
- City of Chesapeake, VA
- Pinellas County, FL
- Sarasota County, FL
- League City, TX
Chesapeake OPAC

Greenbrier Parkway
Military Highway
Portsmouth Boulevard
Taylor Road
Western Branch Boulevard
Deployment History

- **Phase I: mid 2000**
  - Initial installation of MIST traffic management system
  - 3 intersections under OPAC control
  - Serial comm & loop detectors

- **Phases II&III: 2008-present**
  - Intersection controller upgrade
  - Additional adaptive controlled intersections
  - Enhanced communication and detectorization
  - More DMS & CCTV units
Chesapeake – Existing System

- 160 signalized intersections running ASC/2 and ASC/3 NEMA controllers
- 33 intersections on 5 corridors controlled by OPAC adaptive system
- 31 OPAC intersections use ISS RTMS radar detectors
- 23 CCTV cameras and 7 DMS signs
- 54 Detector stations
- Wireless Communication (150+ Encom radios)
  - Encom 900 MHz radios (intersection, DMS and detector stations)
  - Encom 5.8 GHz radios (backhaul & video)
Case Study:
Pinellas Smart tracs ATMS
Phase I Deployment: 2003-2005

- **Install ATMS platform**
  - Two central systems (MIST & i2TMS)
  - Two adaptive control algorithms (OPAC & RHODES)
  - Two different firmware (ASC/2 & Nextphase)
  - 16 OPAC-controlled intersection
- **Magnetic loops detection system**
- **Some limited number of CCTV and DMS units**
2006-2007 Evaluation

- Independent before/after study to determine the adaptive software operation versus traditional time-of-day signal plans
- OPAC US19 *travel times* were reduced by an average of 7.5%, with peak travel times dropping 25%
- Over $1 million in *annual fuel savings* alone as a result of the new system
  - *Benefit/cost ratio* of approximately 7:1

*Courtesy of Pinellas County Public Works*
Success of the System

- 2008 changes to adaptive parameters resulted in an additional reduction of 10%, on average, to the travel times across the corridors

Safety
- **Total accidents** down by 30%, pre-adaptive year crash data vs. post-adaptive year crash data
  - **Rear-end accidents** decreased by 18%
  - **Serious injuries** reduced by 40%

Courtesy of Pinellas County Public Works
# System Components

<table>
<thead>
<tr>
<th>Initial Deployment</th>
<th>Current Vision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two separate ATMS/Adaptive systems</td>
<td>One common platform</td>
</tr>
<tr>
<td>Serial comm (central to field and controller to adaptive control boxes)</td>
<td>Ethernet based with IP addressing</td>
</tr>
<tr>
<td>Upstream detectors directly connected to the receiving downstream intersection</td>
<td>IP based system allows detector data exchange between all intersections</td>
</tr>
<tr>
<td>Detection system: loops with some video detection and CCTV at the intersection</td>
<td>Loops, radar, microwave, VIDs, Sensys Bluetooth data in the work</td>
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</table>
Additional Enhancements

- Additional 36 adaptive-controlled intersections
- Deployment of advanced detection technologies
- Deployment of environmental sensors (precision and distributed models)
  - CO, PM2.5, NO, NOx, NO2
Air Quality Sensors
Air Quality Sensors – McMullen Booth
## Air Quality Data

### Latest Update

<table>
<thead>
<tr>
<th>Mote Address</th>
<th>Last Updated</th>
<th>CO (ppm)</th>
<th>NO (ppb)</th>
<th>NO2 (ppb)</th>
<th>Sound (dBA)</th>
<th>Humidity (%)</th>
<th>Temp (°C)</th>
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Case Study: OPAC Adaptive vs. TOD Particulate Matter (PM)

Avg Weekly Improvement: 17.56%
Case Study: OPAC Adaptive vs. TOD
Carbon Monoxide (CO)

**CO Emission - Weekly**

Avg Weekly Improvement: 11.04%
Local Weather Alerts & Forecast
# Adaptive System Enhancements

<table>
<thead>
<tr>
<th>Original System</th>
<th>Current Vision</th>
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</thead>
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<tr>
<td>Dependency on the specific controller &amp; firmware</td>
<td>Adaptive system should interface with any NTCIP compliant firmware</td>
</tr>
<tr>
<td>Improve mobility/safety using ATMS/adaptive system (proactive)</td>
<td>• ATMS must integrate with ATIS to provide a highly intelligent and proactive system to account for even small variations</td>
</tr>
<tr>
<td></td>
<td>• Take into consideration the close relationship between air quality and traffic conditions</td>
</tr>
<tr>
<td></td>
<td>• Take into consideration impact of the weather on mobility &amp; safety</td>
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Where Are We Today?

- More interest in adaptive systems
- Operational preference: 24/7
- Ease of installation and lower cost
  - Advancement in communication systems and detection technologies
  - IP-based system
    - Peer-to-peer communications
    - Reduced detector installation cost
- Proven technology
- Overall Project Goals: Improve mobility, Improve safety, Reduce environmental impacts
Thank You

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Supported Signal Controllers

- **NTCIP (1/sec polling)**
  - Econolite ASC/2 & ASC/3 (NEMA & 2070)
  - D4 2070
  - Peek ATC-1000, NTCIP (1/sec)

- **Other NTCIP Controllers – In the work**
  - Interface to all NTCIP compliant controllers without dependency on the firmware type
Project Area

- The most densely populated county in Florida
- Lack of limited access highways
- Severe seasonal tourism variations
- Variations in travel and congestion patterns
- Requires continuous changes to signal timing plans & parameters
The OPAC Control Algorithm

Traffic Network
- Surveillance (detector data)
- Phase Flow Characterization

Signal Timings
- Platoons Prediction
- Flow Profiles
  - Smoothed Volume
  - Smoothed Occupancy
  - Average Speed

Intersection Optimization Logic
- Intersection Objective
- Operating Constraints
- Queue Length
  - Stops
  - Delay
- (Iterate)

Intersection Simulation
- Queue Length
- Initial Queue Length
- Initial Stops
- Initial Delay
- Flow Profiles
- Average Speeds
- Initial Signal Status
- Signal Timings

Intersection Geometry
- Discharge Characteristics

-- need to revise in or convert from VISIO --

Jan 23, 2007

Town of Cary Traffic Adaptive System