Reliability, Flexibility, And Environmental Impact Of Alternative Arterial Offset Optimization Objective Functions


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Motivation

There are a number of different opinions on which optimization objective function is best. It is desirable to use high resolution controller data and probe vehicle travel times to compare multiple objective functions to determine which function performs best on a coordinated arterial?

Approach

- Establish a baseline measurement of travel time along an arterial.
- Optimize offset times using four alternative objective functions:
  - Minimize delay
  - Minimize delay and stops
  - Maximize vehicle arrivals on green
  - Maximize vehicle arrivals on green without startup time
- Implement four optimized offsets at eight intersections
- Measure travel times of probe vehicles to assess travel time associated with each objective.
- Calculate the potential driver benefits for changing offset times to accommodate optimal travel time and platoon dispersion.

Offset Objective Function Concept

- Objective I: Minimize delay (d)
  \[ d = \sum_{i} q_i \]
- Objective II: Minimize delay and stops in a performance index (Pi).
  \[ P_i = d + k \sum S_i \]
- Objective III: Maximize arrivals on green (Np) [From Pro-Tracts & ACS/lite]
  \[ N_p = \sum G_i N_i \]
- Objective IV: Maximize arrivals on green with queue clearance time set at 10 seconds

Effect Of Adjusting Local Offset To Shift Vehicle Arrivals With Respect To Green Time

In General, Optimal Offsets Of Each Objective Functions Are Close

Calculated Optimal Offsets Tested On Weekend Plans Along Study Corridor

- Objective I: Minimize Delay
- Objective II: Minimize Delay & Stops
- Objective III: Maximize Arrivals On Green
- Objective IV: Maximize Arrivals On Green With 10s Queue Clearance

- FIVE SATURDAY DATA COLLECTION PERIODS
- AVERAGE SATURDAY VEHICLE VOLUME: ~ 50,000
- TIME OF DAY PLAN: 0600 – 2200
- INTERSECTIONS: 8
- CYCLE LENGTH: 114 Seconds
Quantifying The Potential Driver Benefit Gained By Adjusting Coordinated Signal Offsets For A Saturday Time-of-Day Plan

Flow Profiles For Baseline And Optimized Offsets For The Saturday (0600 – 1800) TOD Plan

System #1

- Northbound
  - Baseline: Optimized (S, B)
  - System #3: Optimized (S, B)

System #2

- Southbound
  - Baseline: Optimized (S, B)
  - System #3: Optimized (S, B)

Measured Travel Times Along Corridor To Assess The Effect Of Offset Change

Objectives (I, II, III, & IV) Travel Times for System #1 and System #2

- Northbound, Case A to Case B (Min)
- Southbound, Case A to Case C (Min)

Objective III

- System #1 Had Been Previously Optimized, with Minimal Travel Time Improvement Measured
- System #2 Had Not Been Previously Optimized and It Showed the Most Improvement to the Travel Time

Flow Profiles Generated from High-Resolution ASC/3 Controller Data at Each of the 8 Intersections

Travel Times Based For Each System and Each Objective

- System 1
  - Min Delay: 29,049 s
  - Max N's: 2,447 s
- System 2
  - Min Delay: 29,164 s
  - Max N's: 2,447 s

Objective CO2 Emission Reduction CO2 User Savings Energy Reduction CO2 User Savings

<table>
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<tr>
<th>Objective</th>
<th>Total Time (Min)</th>
<th>Emission Reduction</th>
<th>CO2 User Savings</th>
<th>Energy Reduction</th>
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Environmental Benefits (System #1, 1.5 miles)

- 77.5 Tons
- 87.0% Reduction
- 47.15$"% Reduction

Estimated Reduction in Fuel Consumption

- 20,300 – 25,500 Gallons
- 197-250 Tons

All Objectives Where Found to Have a Positive Financial and Environmental Impact on The Eight Intersection Study Corridor.

The Improved Weekend Travel Times can be Equated to a Lower Bound Annual User Cost Saving of $471,817.

The Improved Weekend Travel Times Reduce Fuel Consumption and Thus Decrease the Lower Bound Annual Carbon Cost Equivalent by $4,329.