Comparing Common Control Group treatment and coordination of separate signal controllers

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This presentation will discuss the difference in signal timings and network performance resulting from two methods of signal control used for Closely-Spaced (Paired / Compound) Intersections and Interchanges:

- Common Control Group (CCG)
- Signal Coordination

The purpose of the presentation is to explain the reason for differences in signal timing results between the two methods of control.

A simple example is presented using the first principles for signal timing analysis and giving the results from the SIDRA INTERSECTION software.
Common Control Group (CCG) is a SIDRA INTERSECTION software term used for a group of signalised sites (intersections) controlled by a single signal controller.

In this mode of control, a single phase sequence applies to the CCG as a whole, and the signal timing calculations (cycle time and green splits) are done considering all movements in the CCG.

This is relevant to the modelling of signalised closely-spaced (paired) intersections and interchanges.

Alternatively, Signal Coordination of a group of sites (intersections) can be implemented using a common network cycle time and signal offsets.

In this mode of control, separate phase sequences apply to each site (intersection) subject to coordination.

A new cycle time and green split method was developed for Common Control Groups (introduced in SIDRA INTERSECTION Version 7).
Network timing for Signal Coordination (different from Common Control Groups) is based on calculation of:

- **Network Cycle Time**
- **Green Splits** for individual Sites for the Network Cycle Time
- **Offsets** for specified Routes
Signal Platoon Patterns: The general model applicable to both Signal Coordination and Common Control Group modes of control

Using signal offsets, lane-based (not link-based) second-by-second platoon patterns are modelled to estimate:

- Percent Arriving During Green
- Platoon Ratio
- Arrival Types

Option for no PLATOON DISPERSION (for very short distances between intersections)
Articles and presentations on the lane-based analytical network model developed for SIDRA INTERSECTION are downloadable from the ARTICLES page of the SIDRA SOLUTIONS website:
http://www.sidrasolutions.com/Resources/Articles

Also available in RESEARCH GATE:
https://www.researchgate.net
Common Control Group timing method is relevant to Closely-Spaced (Paired) Intersections and Interchanges

As a basis for parameters to be used in timing calculations, a lane-based network capacity and performance model is particularly important for closely-spaced (paired) intersections and interchanges with:

- high demand flows
- lane blockage by downstream (back of) queues that may occur
- limited opportunities for lane changing between intersections leading to unequal lane use.
Estimation of saturation flow rates to be used in timing calculations

The orange-coloured boxes and lines in this flow chart show the unique aspects of the SIDRA INTERSECTION network model.

Estimation of this KEY PARAMETER is important for signal timings and performance estimates.

Network timing calculations can be done using saturation flow rates with and without the effect of lane blockage.

The central role of BACK OF QUEUE (average and probabilities) in this process is emphasised.
Unequal lane use at Closely-Spaced (Paired) Intersections and Interchanges

Modelling of unequal lane use at closely-spaced intersections is emphasised (significant effects on traffic performance and signal timing results).

This method coupled with a lane-based model allowing for:

- the backward spread of congestion,
- upstream capacity constraint,
- special movement classes,
- midblock lane changes,
- as well as features such as short lane overflow

produces improved results in assessing signal coordination quality and optimising signal offsets.

Upstream lane blockage by internal approach lane queues to be avoided.
Modelling lane use at Closely-Spaced (Paired) Intersections and Interchanges

Freeway Traditional Diamond Interchange

Lane use at closely-spaced intersections and interchanges have important effect on signal timings.

Lane allocation by SPECIAL MOVEMENT CLASSES for turning movements.

Through traffic in different lanes have different destinations downstream.
Application to Alternative (Innovative) Intersections and Interchanges

Diverging Diamond Interchange

Lane use at closely-spaced intersections and interchanges has an important effect on signal timings

Lane allocation by SPECIAL MOVEMENT CLASSES for turning movements

Through traffic in different lanes have different destinations downstream
Simple Example for Common Control Group signal timings:
Purpose of the example and input data

Purpose of the example:
Applying the first principles, show the difference between signal timing analysis results (Cycle Time and Phase Times) for
- Coordinated Signals (two signal controllers)
- Common Control Group (one signal controller)

Midblock Approach Distance = 180 m
In this example, a large value is chosen to avoid lane blockage effects so that only the effects on Cycle Time and Phase Times are compared.
Simple Example for Common Control Group signal timings: Flow Ratios and basic signal timing equations

FLOW RATIOS

\[ y = \frac{\text{Arrival Flow}}{\text{Saturation Flow}} \]

Saturation Flow Rate = 1800 veh/h (all lanes)

Total (Intersection) Flow Ratios:
- Site 101: \( Y = 0.50 + 0.20 = 0.70 \)
- Site 102: \( Y = 0.40 + 0.30 = 0.70 \)

Intersection values are the same \( (Y = 0.70) \) for both sites but movement values (therefore Phase Time demands) are different.

Lost Time, \( L = 2 \)

\[ l_i = 2 \times 5 = 10 \text{ s} \]

Site 102

\[ y_2 = 0.30 \]

\[ y_1 = 0.40 \]

Site 101

\[ y_2 = 0.20 \]

\[ y_1 = 0.50 \]

Cycle Time, \( c = \frac{L}{(1 - Y / 0.90)} \)

Green Times, \( g_i = \frac{(c - L)}{Y} y_i \)

Phase Times, \( p_i = l_i + g_i \)
Simple Example for Common Control Group signal timings:
Cycle Time and Phase Times for TWO SEPARATE CONTROLLERS

**Site 102**
Flow Ratio: \( Y = 0.40 + 0.30 = 0.70 \)
Lost Time, \( L = 2 \times 5 = 10 \text{ s} \)
Cycle Time, \( c = 45 \text{ s} \)
Green Times, \( g_1 = 20 \text{ s}, g_2 = 15 \text{ s} \)
Phase Times, \( P_1 = 25 \text{ s}, P_2 = 20 \text{ s} \)

**Site 101**
Flow Ratio: \( Y = 0.50 + 0.20 = 0.70 \)
Lost Time, \( L = 2 \times 5 = 10 \text{ s} \)
Cycle Time, \( c = 45 \text{ s} \)
Green Times, \( g_1 = 25 \text{ s}, g_2 = 10 \text{ s} \)
Phase Times, \( P_1 = 30 \text{ s}, P_2 = 15 \text{ s} \)

* Critical movements for each Site shown
Simple Example for Common Control Group signal timings: Cycle Time and Phase Times for SINGLE CONTROLLER

Analysis as a Common Control Group

Common Control Group
Flow Ratio: \( Y = 0.50 + 0.30 = 0.80 \)
Lost Time, \( L = 2 \times 5 = 10 \text{ s} \)
Cycle Time, \( c = 90 \text{ s} \)
Green Times, \( g_1 = 50 \text{ s}, g_2 = 30 \text{ s} \)
Phase Times, \( P_1 = 55 \text{ s}, P_2 = 35 \text{ s} \)

* Critical movements for CCG shown
Simple Example for Common Control Group signal timings: Results from SIDRA INTERSECTION

<table>
<thead>
<tr>
<th>Practical Cycle Time (EQUISAT for $x_p = 0.90$)</th>
<th>Optimum Cycle time (Minimum-Delay)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Separate Sites (Isolated)</strong></td>
<td><strong>Separate Sites (Isolated)</strong></td>
</tr>
<tr>
<td>Site 101: $c = 45$ (P = 30, 15)</td>
<td>Site 101: $c = 80$ (P = 55, 25)</td>
</tr>
<tr>
<td>Site 102: $c = 45$ (P = 25, 20)</td>
<td>Site 102: $c = 60$ (P = 34, 26)</td>
</tr>
<tr>
<td>$X = 0.900, d = 26.4, d_{max} = 29.9$</td>
<td>$X = 0.857, d = 22.1, d_{max} = 35.2$</td>
</tr>
<tr>
<td><strong>Coordinated</strong></td>
<td><strong>Coordinated</strong></td>
</tr>
<tr>
<td>Site 101: $c = 45$ (P = 30, 15)</td>
<td>Site 101: $c = 65$ (P = 46, 19)</td>
</tr>
<tr>
<td>Site 102: $c = 45$, (P = 25, 20)</td>
<td>Site 102: $c = 65$ (P = 38, 27)</td>
</tr>
<tr>
<td>$X = 0.900, d = 22.5, d_{max} = 29.9$</td>
<td>$X = 0.929, d = 20.2, d_{max} = 44.8$</td>
</tr>
<tr>
<td><strong>Common Control Group</strong></td>
<td><strong>Common Control Group</strong></td>
</tr>
<tr>
<td>$c = 90$ (P = 55, 35)</td>
<td>$c = 110$ (P = 68, 42)</td>
</tr>
<tr>
<td>$X = 0.900, d = 27.8, d_{max} = 45.1$</td>
<td>$X = 0.892, d = 27.5, d_{max} = 50.0$</td>
</tr>
</tbody>
</table>

- $c$ = Cycle Time (seconds)
- $P$ = Phase Times (seconds)
- $X$ = Largest Degree of Saturation for any movement in the network
- $d$ = Average Delay for all movements in the network (seconds)
- $d_{max}$ = Largest Delay for any movement in the network (seconds)
Simple Example for Common Control Group signal timings:
Signal coordination effects and Northbound travel performance

**Signal Coordination**

**Optimum Cycle Time = 65**

Platoon Ratio: 1.619, Arrival Type = 5
Route Travel Time = 91.8 s, Route Delay = 18.6 s

**Optimum Cycle Time = 110**

Platoon Ratio: 1.517, Arrival Type = 5
Route Travel Time = 107.2 s, Route Delay = 34.0 s

**Network results**

- Platoon Ratio: 1.619, Arrival Type = 5
  - Route Travel Time = 91.8 s
  - Route Delay = 18.6 s
  - Optimum Cycle Time = 65

- Platoon Ratio: 1.517, Arrival Type = 5
  - Route Travel Time = 107.2 s
  - Route Delay = 34.0 s
  - Optimum Cycle Time = 110
**Simple Example for Common Control Group signal timings:**

**Use of LATE START**

Early Cut-Off and Late Start parameters are commonly used to improve the performance of the Common Control Group method.

In the example, LATE START = 10 s specified for South approach of the North Site (102).

- \( c = 122 \) (P = 76, 46)
- \( X = 0.893 \), \( d = 28.4 \), \( d_{\text{max}} = 54.0 \)

**Common Control Group (Late Start)**

**Optimum Cycle Time = 122 s**

- Platoon Ratio: **1.778**, Arrival Type = **5**
- Route Travel Time = **106.1 s**, Route Delay = **32.9 s**
Simple Example for Common Control Group signal timings: 
Use of EARLY CUT-OFF

In the example, EARLY CUT-OFF = 10 s specified for South approach of the South Site (101).

\[ c = 140 \ (P = 90, 50) \]
\[ X = 0.933, \ d = 39.8, \ d_{max} = 71.4 \]

Common Control Group (Early Cut-Off)  
Optimum Cycle Time = 140 s

Platoon Ratio: 1.564, Arrival Type = 5  
Route Travel Time = 123.9 s, Route Delay= 50.8 s
Conclusions

- Significantly worse results for CCG compared with Signal Coordination mainly due to longer cycle time resulting from worse combination of critical movement green time requirements.

- This was shown using the Flow Ratio parameters in the example given in this presentation to explain the reason for worse performance in terms of the first principles of signal timing analysis.
Conclusions

- More complicated cases in real life due to:
  - Short Lanes
  - Opposed (filter) turns
  - Unequal lane use
  - Lane blockage and capacity constraint effects
  - Midblock lane changes
  - Use of Early Cut-Off and Late Start features

See the example in ARRB 2014 Conference paper:
End of Presentation

Thank you!