Comparing Common Control Group treatment and coordination of separate signal controllers

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The Presentation

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.

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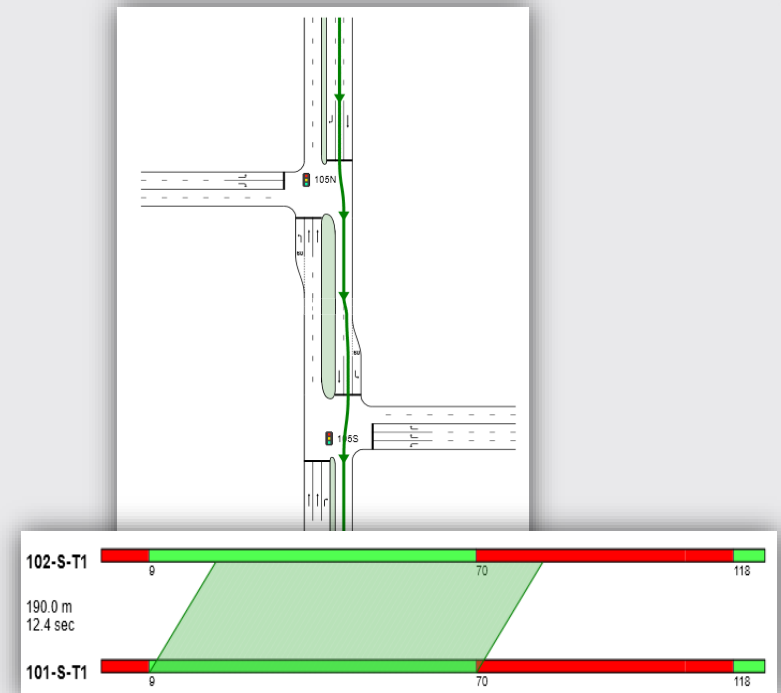
Common Control Groups

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.
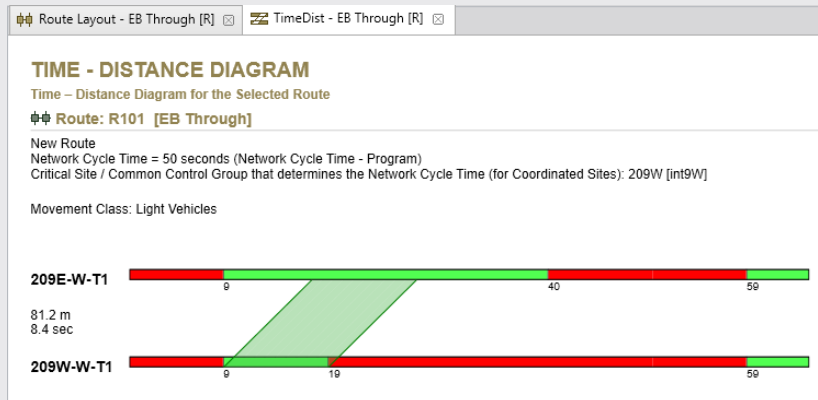
A new **cycle time and green split** method was developed for **Common Control Groups** (introduced in SIDRA INTERSECTION Version 7).

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Network timing method for Signal Coordination

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**

Number of arrivals during red

Number of arrivals during green

red time

green time

cycle time
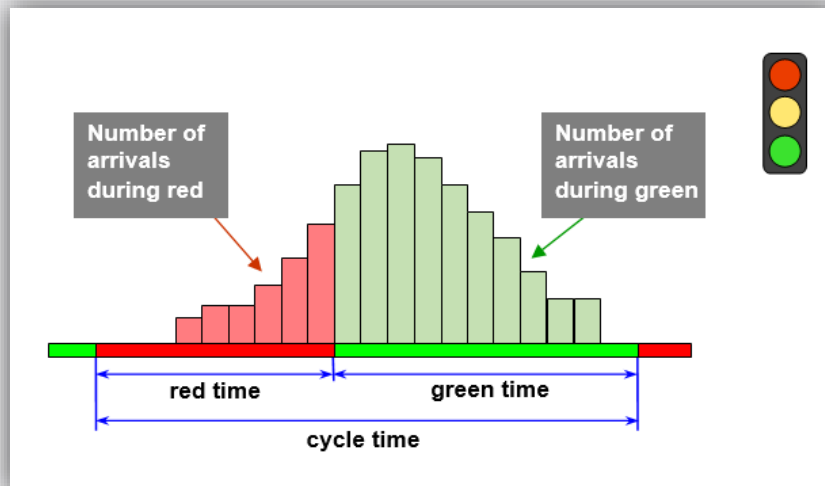
Option for no PLATOON DISPERSION (for very short distances between intersections)

Adjustment for overlap with unqueued vehicles

Dispersion at downstream stop line

q_p

q_u

Dispersion between L_{min} and L_{it}

V_{ac}

L_{it}

q_{pmin}

Dispersion will start here if $f_{pmin} = 1.0$ (default)

q_u

Dispersion will apply along the L_{min} distance if $f_{pmin} > 1.0$ as shown here

s

L_{min}

q_u

Distance

Queued vehicles

No dispersion within the intersection negotiation area

s

Unqueued vehicles

L_{en}

q_u

Time

g_q

g

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SIDRA INTERSECTION Network Model
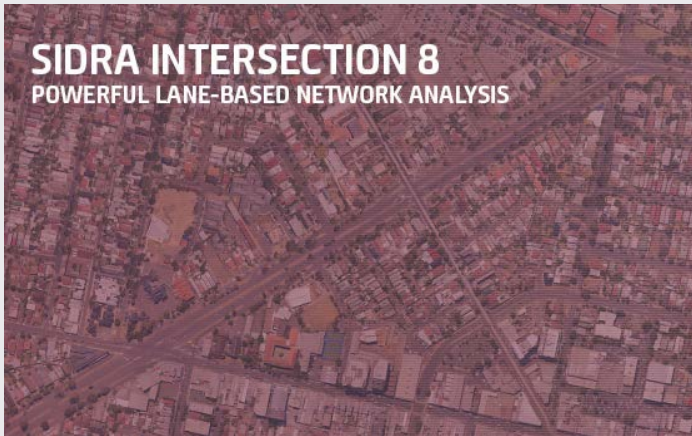
Articles and presentations on the
lane-based analytical network model
developed for SIDRA INTERSECTION
are downloadable from the **ARTICLES** page of the
SIDRA SOLUTIONS website:
http://www.sidrasolutions.com/Resources/Articles

Also available in **RESEARCH GATE:**
https://www.researchgate.net

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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.

Staggered T Intersections

Wide-Median Intersections
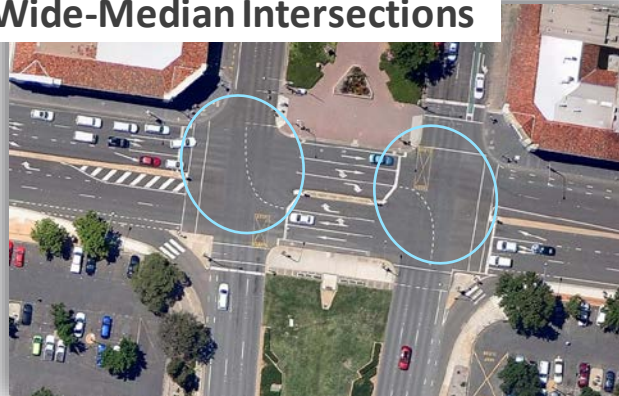
Fully Signalised Roundabout

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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 **orange-coloured boxes and lines** in this flow chart show the unique aspects of the **SIDRA INTERSECTION** network model.
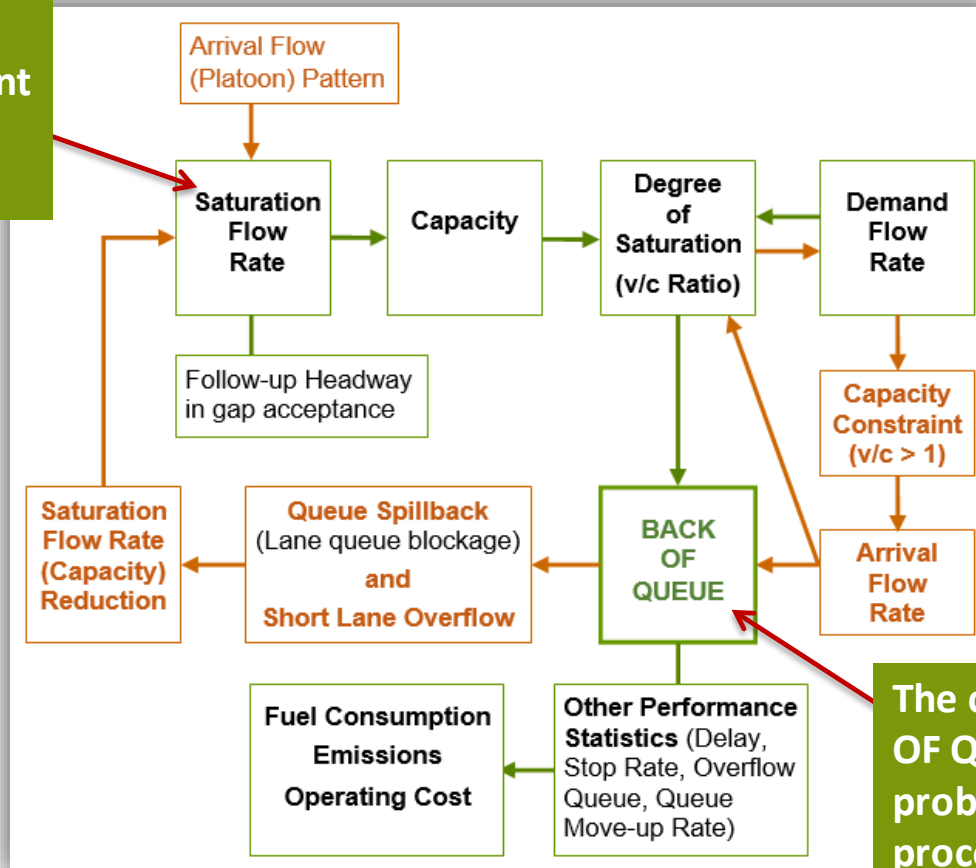
The central role of BACK OF QUEUE (average and probabilities) in this process is emphasised.

Arrival Flow (Platoon) Pattern

Saturation Flow Rate

Capacity

Degree of Saturation (v/c Ratio)

Demand Flow Rate

Follow-up Headway in gap acceptance

Capacity Constraint (v/c > 1)

Saturation Flow Rate (Capacity) Reduction

Queue Spillback (Lane queue blockage) and Short Lane Overflow

BACK OF QUEUE

Arrival Flow Rate

Fuel Consumption Emissions Operating Cost

Other Performance Statistics (Delay, Stop Rate, Overflow Queue, Queue Move-up Rate)

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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**.

LANE UNDER-UTILISATION in paired (closely-spaced) intersections

Upstream lane blockage by internal approach lane queues to be avoided

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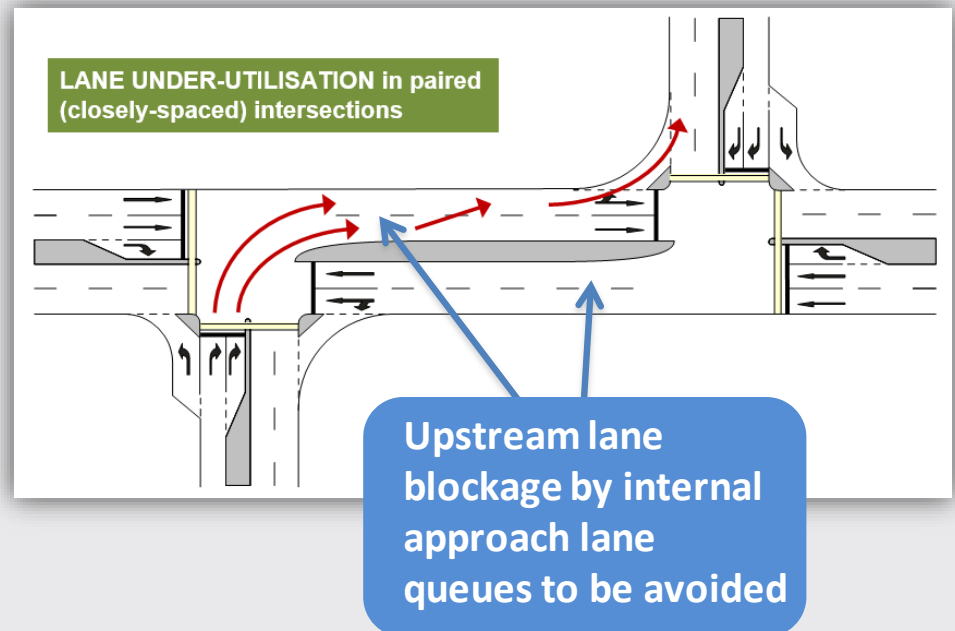
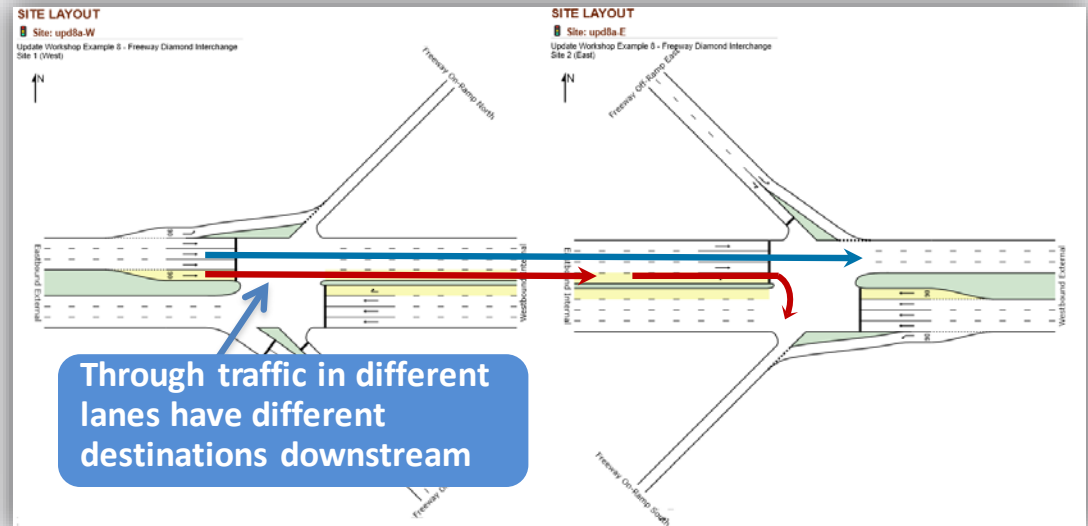# Modelling lane use at Closely-Spaced (Paired) Intersections and Interchanges

Freeway Traditional Diamond Interchange

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

Image:-nearmap.com

Lane allocation by SPECIAL MOVEMENT CLASSES for turning movements

Through traffic in different lanes have different destinations downstream

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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

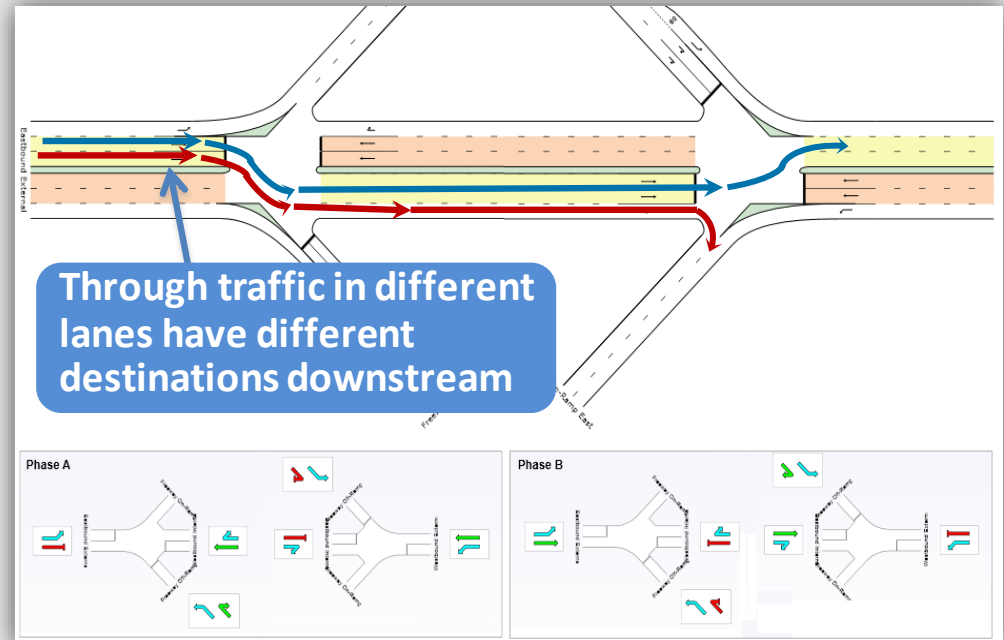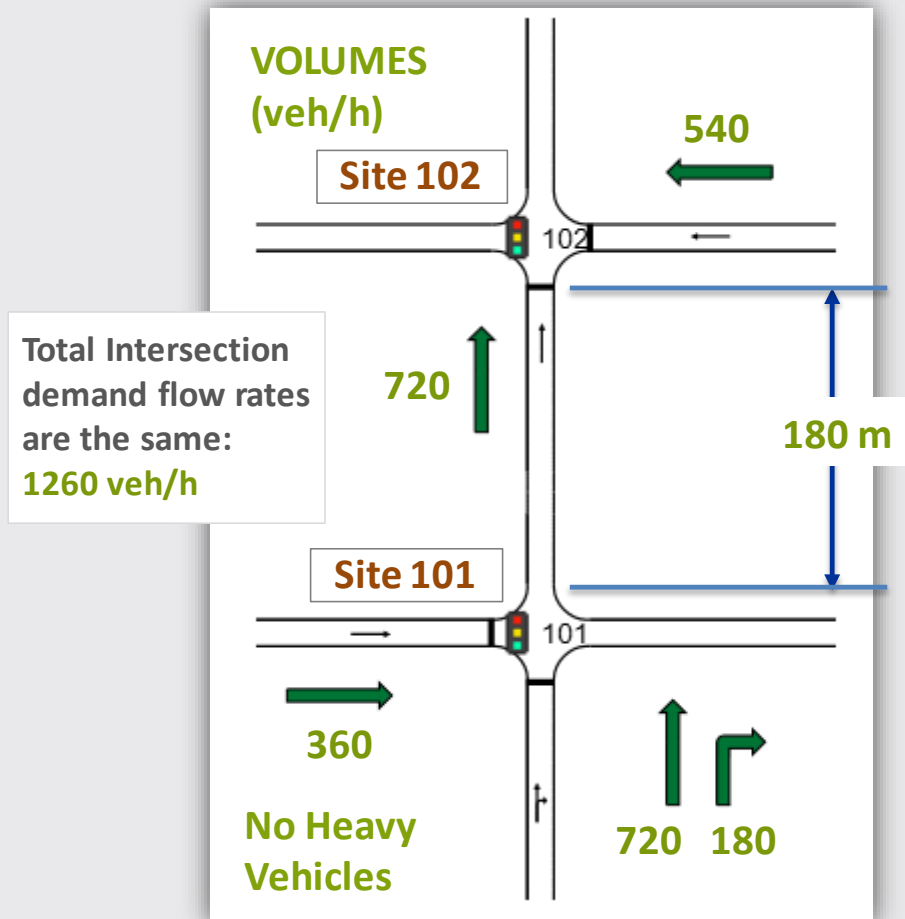Lane allocation by SPECIAL MOVEMENT CLASSES for turning movements

Through traffic in different lanes have different destinations downstream

Phase A

Phase B

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VOLUMES (veh/h)

Site 102

540

720

180 m

Site 101

Total Intersection demand flow rates are the same: 1260 veh/h

360

No Heavy Vehicles

720   180

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.

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Simple Example for Common Control Group signal timings: Flow Ratios and basic signal timing equations

FLOW RATIOS
y = Arrival Flow / Saturation Flow

Site 102
Y = 0.70
$y_2 = 0.30$
$y_1 = 0.40$

Site 101
Y = 0.70
$y_2 = 0.20$
$y_1 = 0.50$
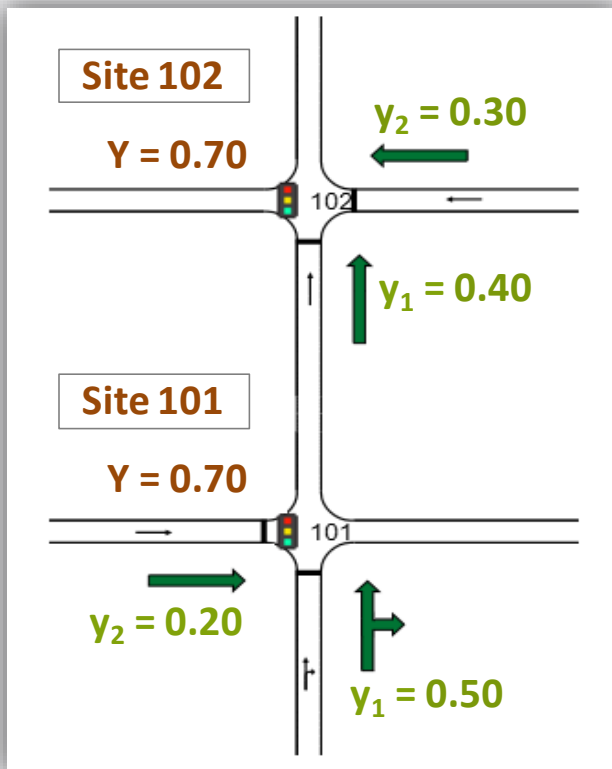
Saturation Flow Rate = **1800 veh/h** (all lanes)

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.
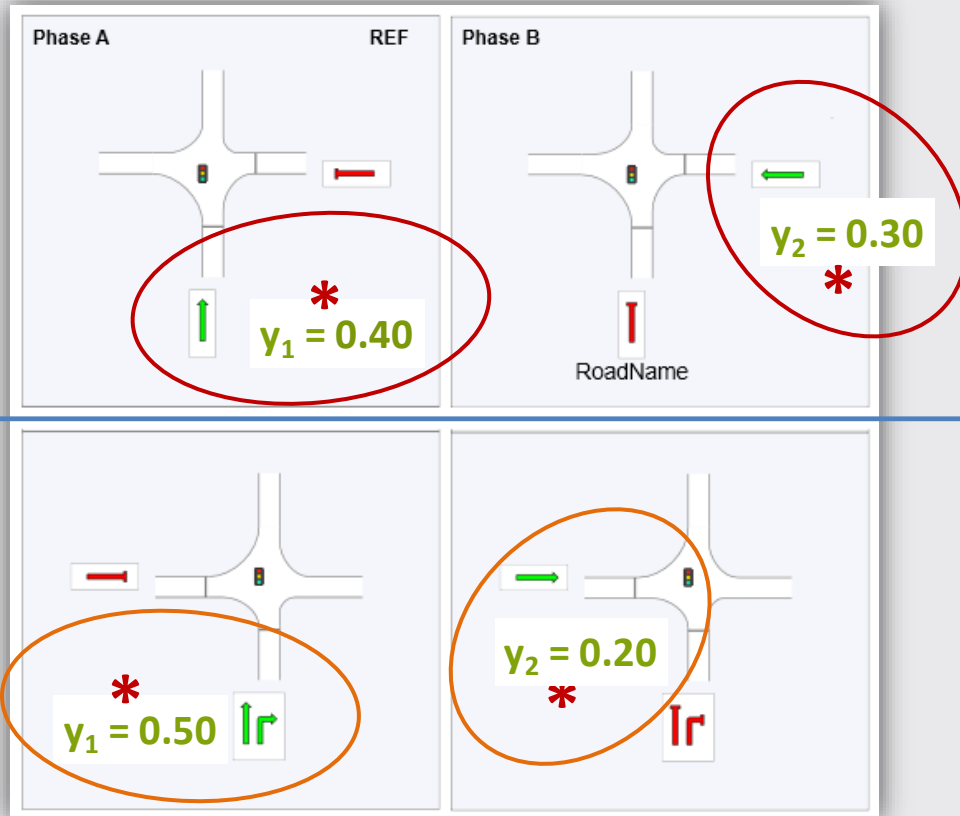
Lost Time, L = 2 l_i = 2 x 5 = 10 s

Cycle Time, c = L / (1 − Y / 0.90)

Green Times, g_i = (c − L) y_i / Y

Phase Times, P_i = l_i + g_i

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Simple Example for Common Control Group signal timings: Cycle Time and Phase Times for TWO SEPARATE CONTROLLERS

Analysis as two separate controllers

Site 102

Flow Ratio: $Y = 0.40 + 0.30 =$ **0.70**
Lost Time, $L = 2 \times 5 =$ **10 s**

Cycle Time, $c =$ **45 s**

Green Times, $g_1 = 20$ s, $g_2 = 15$ s
Phase Times, $P_1 = 25$ s, $P_2 = 20$ s

Site 101

Flow Ratio: $Y = 0.50 + 0.20 =$ **0.70**
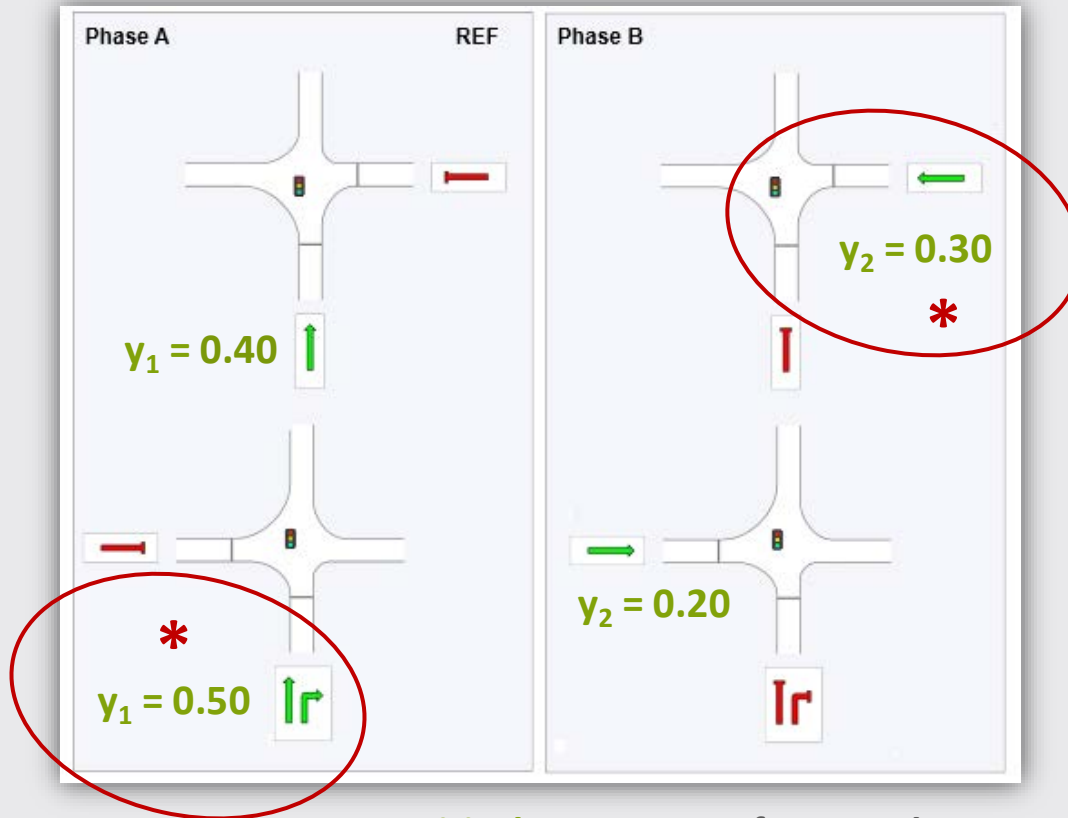Lost Time, $L = 2 \times 5 =$ **10 s**

Cycle Time, $c =$ **45 s**

Green Times, $g_1 = 25$ s, $g_2 = 10$ s
Phase Times, $P_1 = 30$ s, $P_2 = 15$ s

* **Critical movements** for each Site shown

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Simple Example for Common Control Group signal timings: Cycle Time and Phase Times for SINGLE CONTROLLER

Analysis as a Common Control Group

Phase A	REF	Phase B

$y_2 = 0.30$ *

$y_1 = 0.40$

$y_1 = 0.50$ *

$y_2 = 0.20$

Common Control Group

Flow Ratio: $Y = 0.50 + 0.30 = $ **0.80** ↗

Lost Time, $L = 2 \times 5 = $ **10 s**

Cycle Time, $c = $ **90 s** ↗

Green Times, $g_1 = $ **50 s**, $g_2 = $ **30 s**

Phase Times, $P_1 = $ **55 s**, $P_2 = $ **35 s**

* **Critical movements for CCG shown**

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Simple Example for Common Control Group signal timings: Results from SIDRA INTERSECTION

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

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)

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Simple Example for Common Control Group signal timings: Signal coordination effects and Northbound travel performance

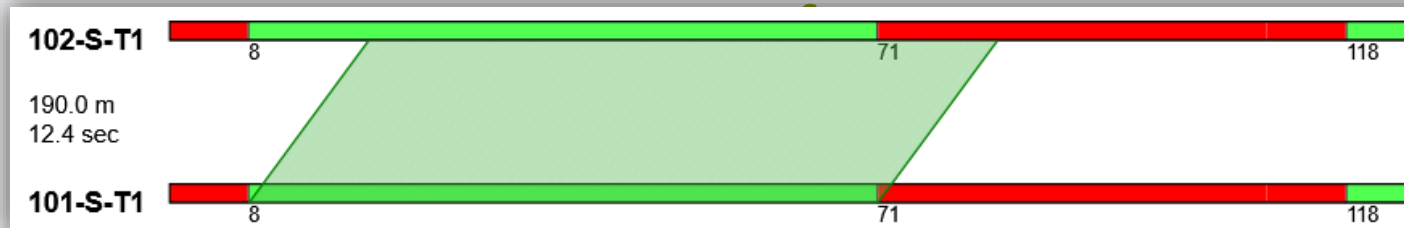**Signal Coordination**   **Optimum Cycle Time = 65**

102-S-T1
190.0 m
12.4 sec
101-S-T1
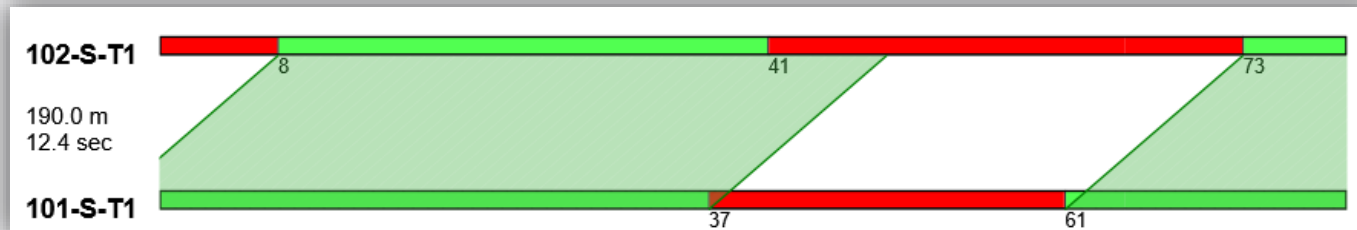
Network results

X = 0.929, d = 20.2, d_{max} = 44.8

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

Common Control Group   **Optimum Cycle Time = 110**

102-S-T1
190.0 m
12.4 sec
101-S-T1

Network results

X = 0.892, d = 27.5, d_{max} = 50.0

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

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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)

$X = 0.893$, $d = 28.4$, $d_{max} = 54.0$

Common Control Group (Late Start)   **Optimum Cycle Time = 122 s**


```
102-S-T1  [red] [======green======] [red]
            18                    79

190.0 m
12.4 sec

101-S-T1  [red] [======green======] [red] [green]
          8                        79        130
```

Platoon Ratio: 1.778, Arrival Type = 5
Route Travel Time = 106.1 s, Route Delay= 32.9 s

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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**


```
102-S-T1    8                                93        148

190.0 m
12.4 sec

101-S-T1    8                          83              148
```

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

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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.**

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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:

AKÇELIK, R. (2014) A new lane-based model for platooned patterns at closely-spaced signalised intersections. Paper presented at the 26th ARRB Conference, Sydney, Australia, Oct 2014. (http://www.sidrasolutions.com/Resources/Articles)
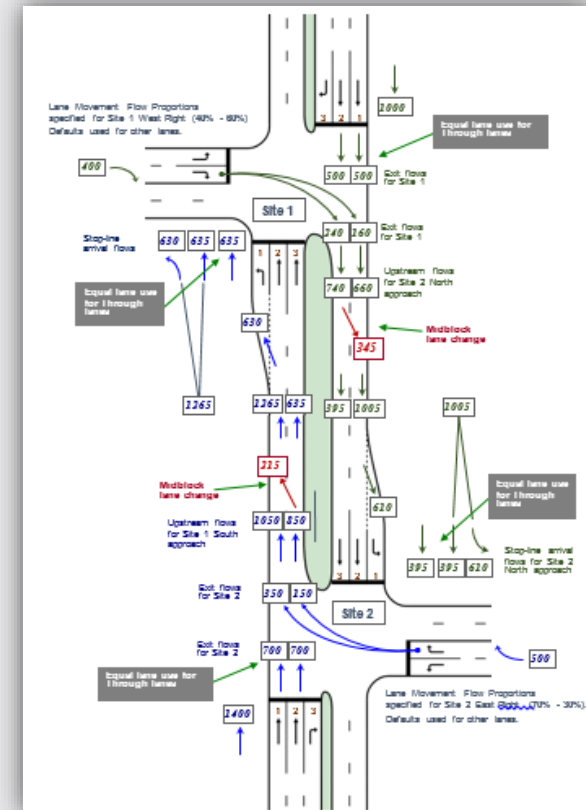
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End of Presentation

Thank you!

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