Development of Network Signal Timing Methodology in SIDRA INTERSECTION

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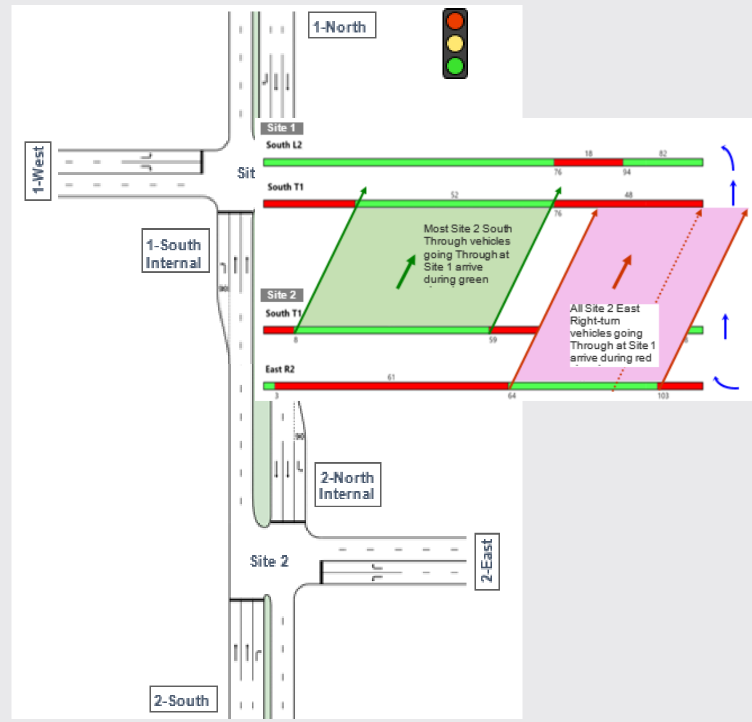
Development of Network Signal Timing Methodology in SIDRA INTERSECTION

Direct Elements of Network Signal Timing

- Lane-based platoon model (using signal offsets)
- Network Cycle Time and Site Phase Time calculations
- Offset calculations (Route based)
- Common Control Groups



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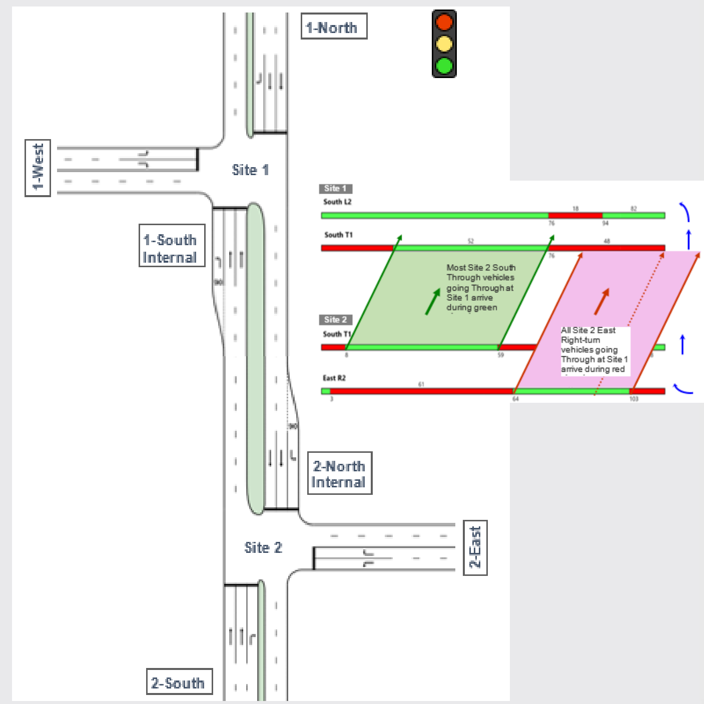
Development of Network Signal Timing Methodology in SIDRA INTERSECTION

❖ PLATOON MODEL

- **Lane-based** model
- Platoons by **Movement Class** (**Special MCs** for downstream turning movements)
- **Second-by-second** arrival and departure patterns
- **Platoon dispersion**
- Output: Percent Arriving During Green, **Platoon Ratio**, Arrival Types



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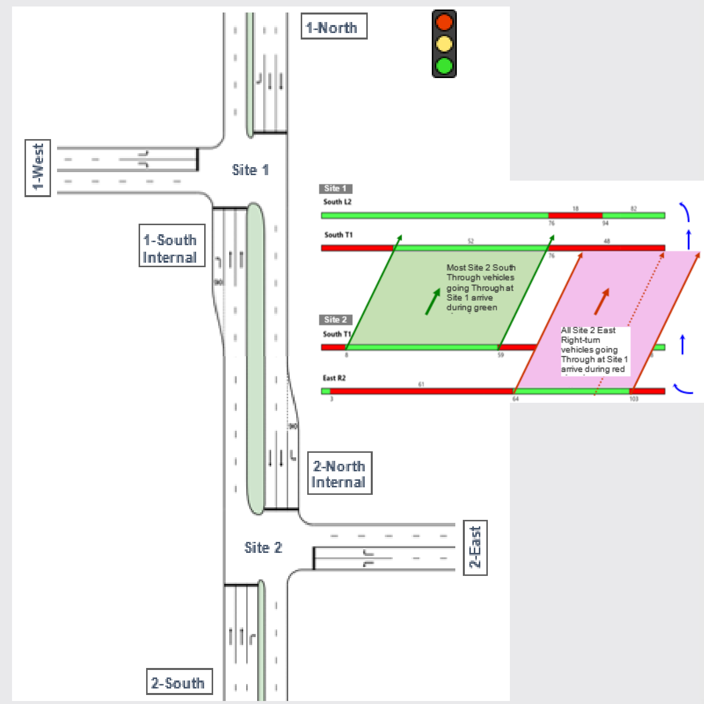
Indirect Aspects of the Network Model

- **Lane Blockage**
  (upstream saturation flow rates are reduced)
- **Capacity Constraint**
  (downstream arrival flow rates are reduced)
- **Lane Movements** at intersections
- Midblock **lane changes**



SIDRA INTERSECTION Background

First released in 1984

Continuous development in response to user feedback

SIDRA INTERSECTION 6.0 | 6.1 | 7.0 (NETWORK Model)

Version 6.0 released in April 2013 and improved significantly after release.

Biggest changes in the 30-year history of the software

- Network Model
- Movement Classes

Version 6.1 released in Feb 2015

Version 7.0 expected to be released during late 2015 / early 2016

Over 7700 Licences
(1836 Organisations) in 84 Countries

SIDRA INTERSECTION recent developments related to Network Signal Timing (Versions 6.1 and 7)

Version 6.1

- New model for signal coordination effects using SIGNAL OFFSETS and lane-based second-by-second platoon patterns including lane changes and platoon dispersion

Version 7

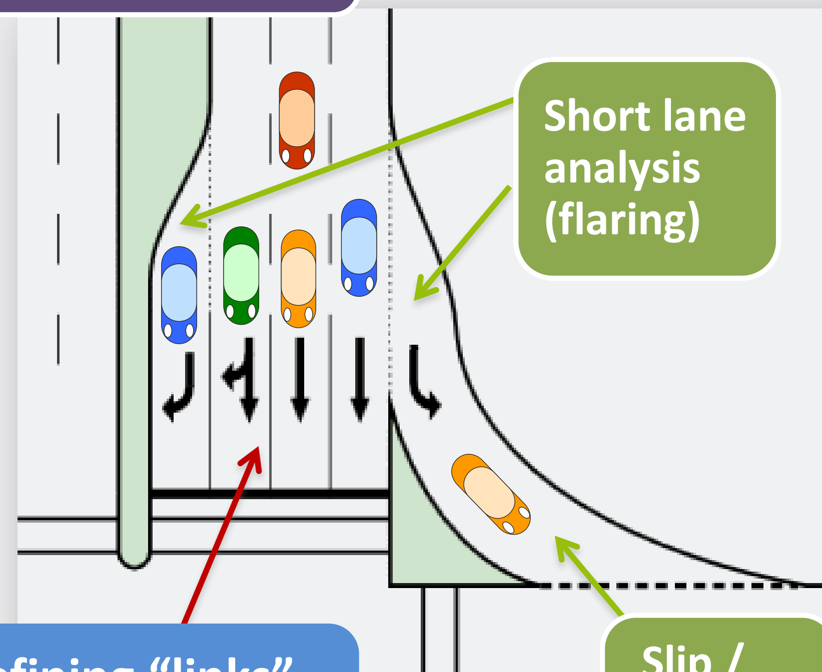
- Network CYCLE TIME calculations
- SIGNAL OFFSET calculations
- Common Control Groups (multiple Sites controlled by a single controller)
- ROUTES for signal Offset calculations
- More User Movement Classes

Lane-based model for intersections

LANE-BASED MODEL

More realistic and reliable analysis compared with approach-based and lane group (link) - based methods (various UK models and US HCM).

- General: Unequal lane flows, de facto exclusive lanes, short lanes, slip/bypass lanes (give-way/yield, continuous, signals).
- Roundabouts: Circulating lane use; Dominant and subdominant lanes.
- NETWORK Model (lane queues, lane blockage, signal platoon arrival and departure patterns).



Movement Classes

Light Vehicles

Heavy Vehicles

Buses

Bicycles

Large Trucks

Light Rail / Trams

Two User Classes for special treatment

Combined with the lane-based method, new Movement Classes allow modeling of **Bus Priority Lanes**, **Bicycle Lanes**, and so on …

Site Origin-Destination Movements by Movement Class as a basis of all data and modelling

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SIDRA NETWORK Model

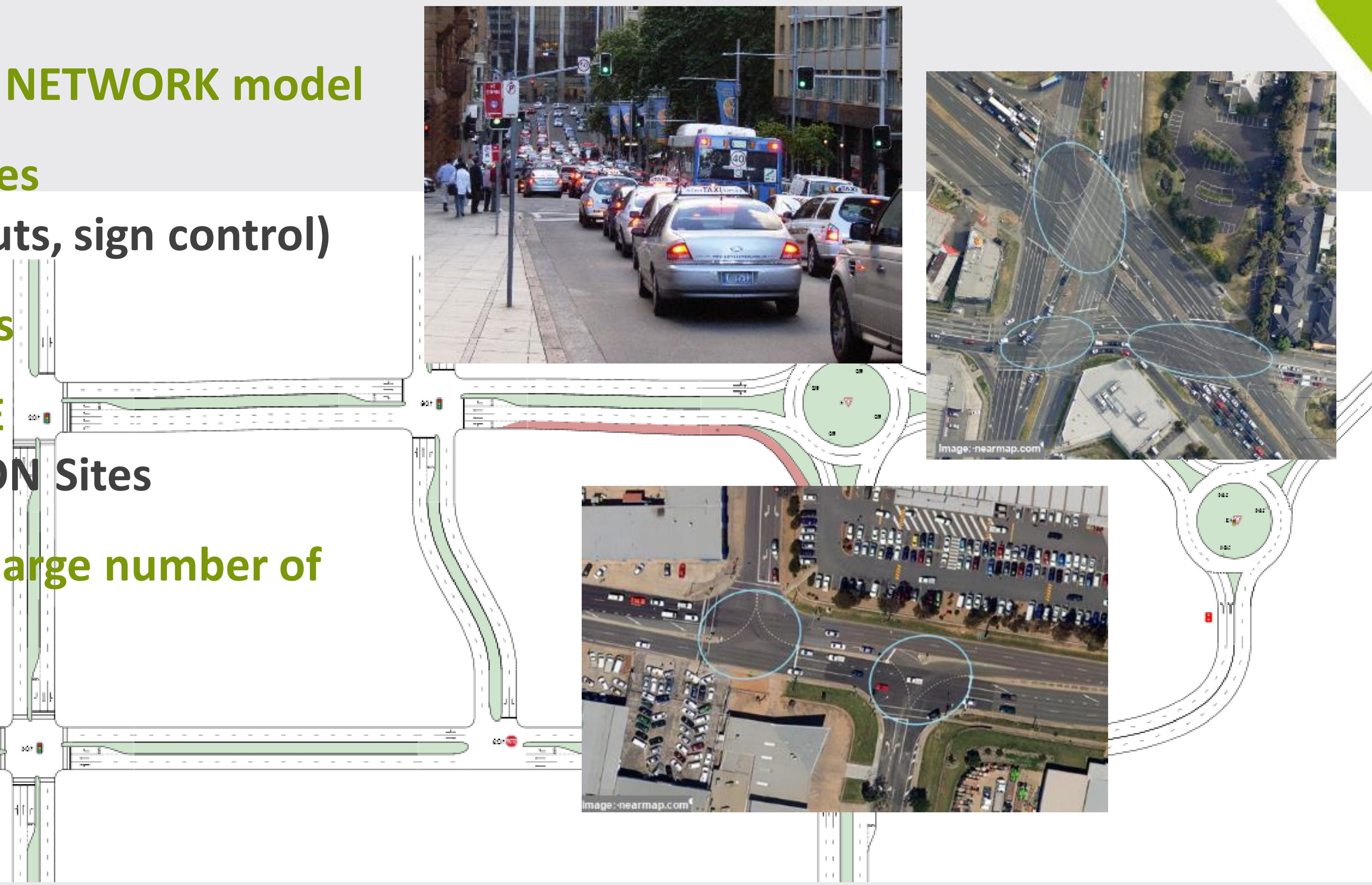
Unique lane-based NETWORK model

All intersection types
(signals, roundabouts, sign control)

Paired Intersections

Easy to CONFIGURE
SIDRA INTERSECTION Sites

Easy to compare a large number of scenarios quickly.



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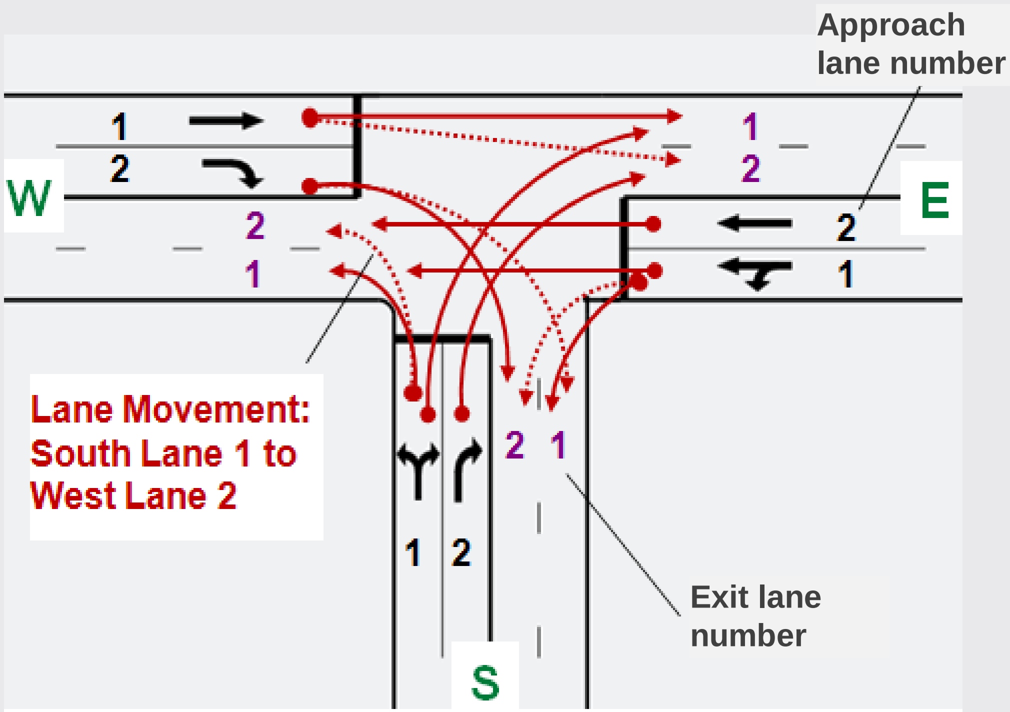
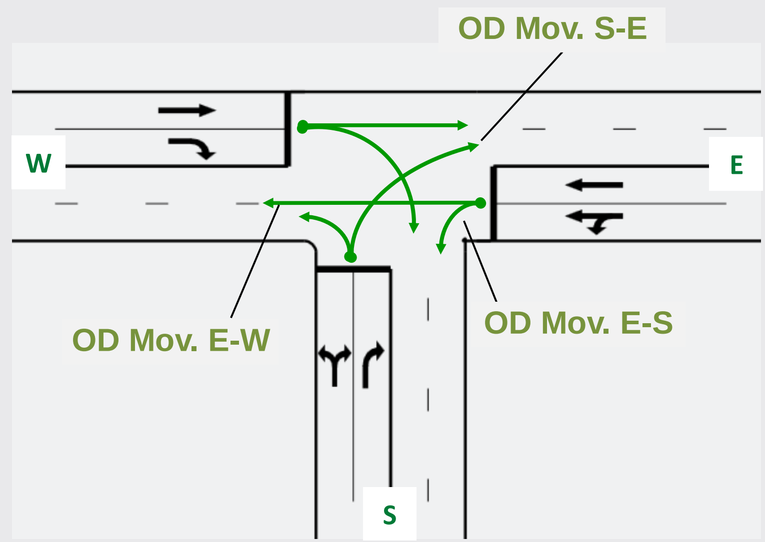
LANE MOVEMENTS



Origin – Destination (OD) Movements



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Departure patterns at upstream lanes

Backward spread of congestion (reduced upstream capacity) ⇄ **Capacity constraint (reduced downstream arrival flows)**

Backward spread of congestion and **capacity constraint** are highly interactive with opposing effects.

SIDRA INTERSECTION uses a **network-wide iterative process** to find a solution that balances these opposing effects.

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Lane-based Model for Networks

Departure patterns per lane are split by
OD movements and by Movement Classes

Platoons move to downstream intersection

Midblock lane changes

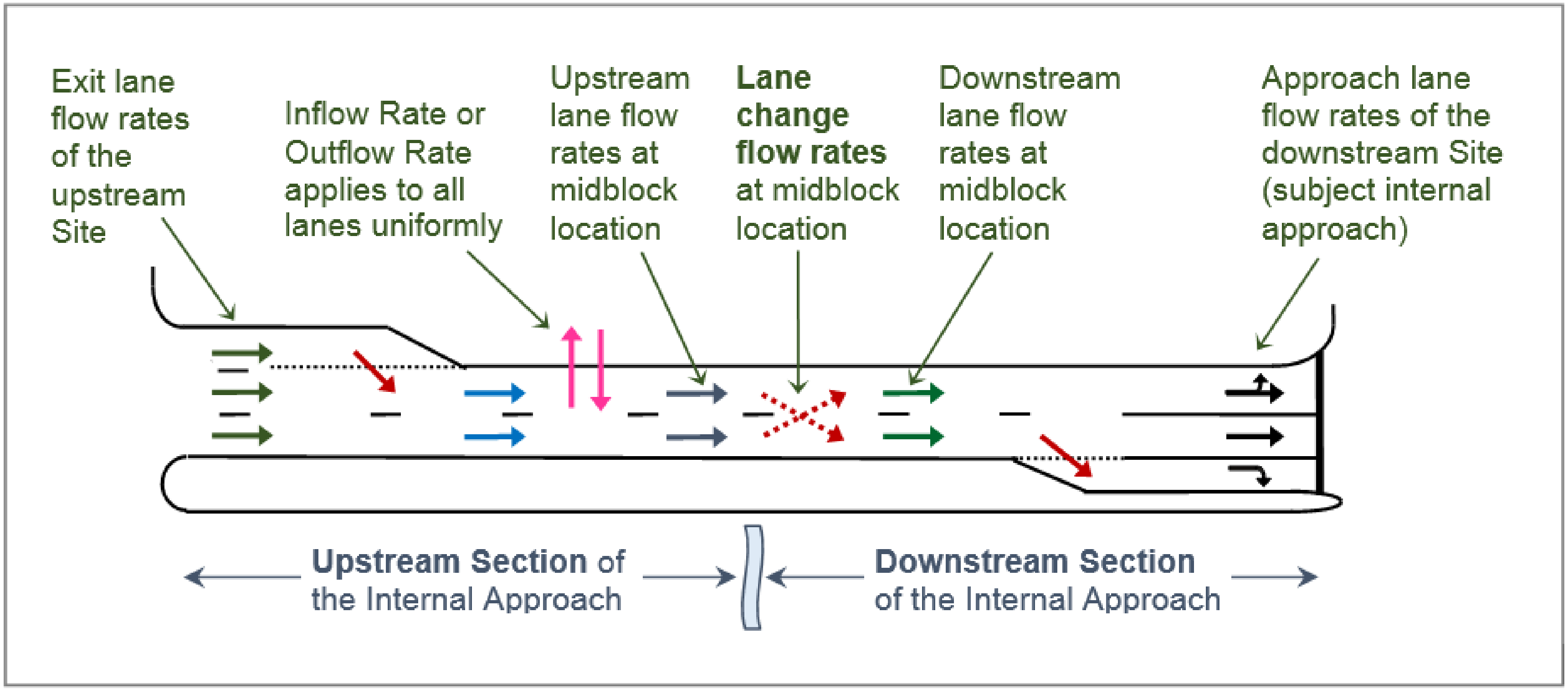
- Exit Short Lane flows merge into adjacent lanes
- Net Inflows allocated to available lanes equally and as uniform patterns
- Net Outflows reduced from midblock patterns in all lanes proportionally
- Midblock lane changes for upstream flow rates to match downstream approach lane flow rates according to OD-MC movements and lane disciplines
- Arrival flows diverge to Approach Short Lanes

Figures in next two slides

Lane-based model for NETWORKS

Midblock Lane Changes

Second-by-second platoon patterns move accordingly



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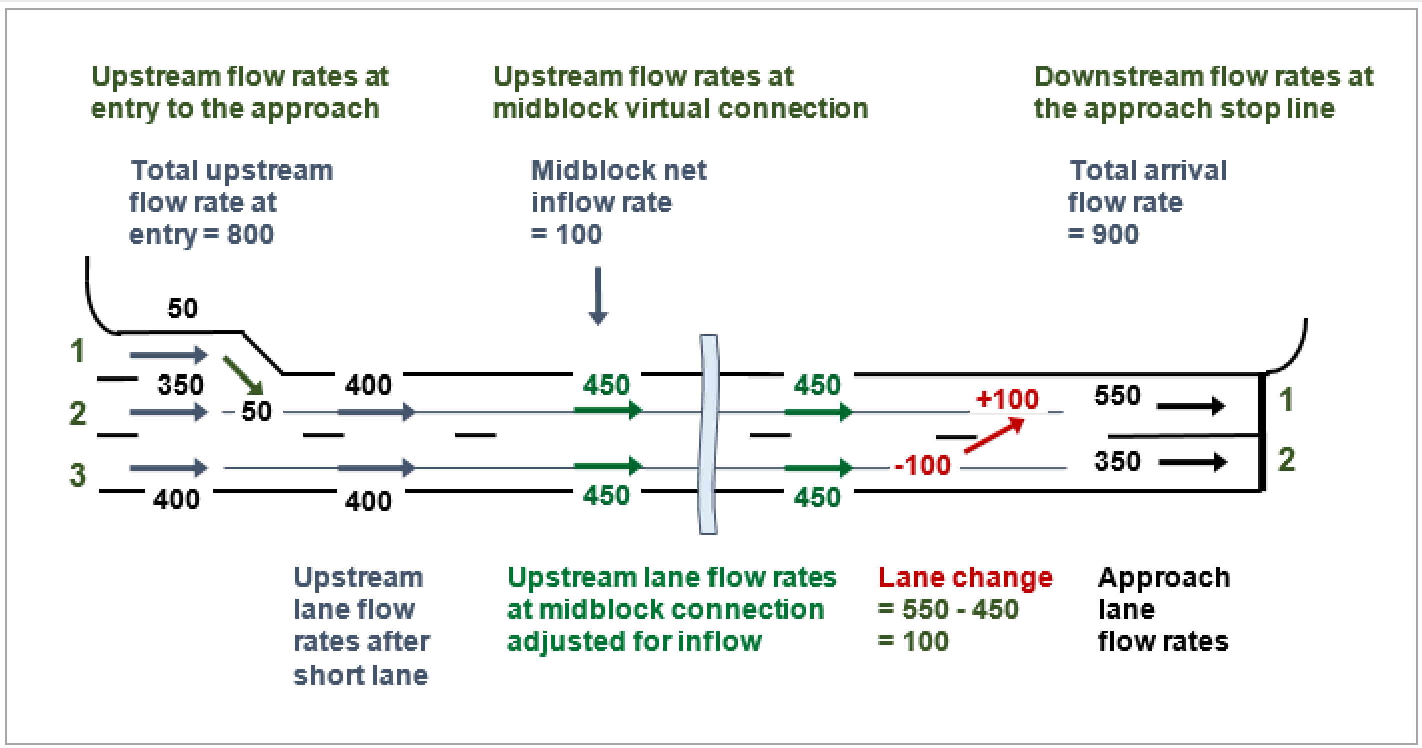
Lane-based model for NETWORKS

Example with Net Inflow

Second-by-second platoon patterns move accordingly



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Departure patterns at upstream lanes

Modelling of departure patterns at upstream lanes takes into account

- capacity reduction due to lane blockage by downstream queues (reduced saturation flow rates affect required movement times)
- reduced arrival flows at downstream lanes due to capacity constraint at oversaturated upstream lanes
- lane movement flow proportions (these determine exit lane flow rates).

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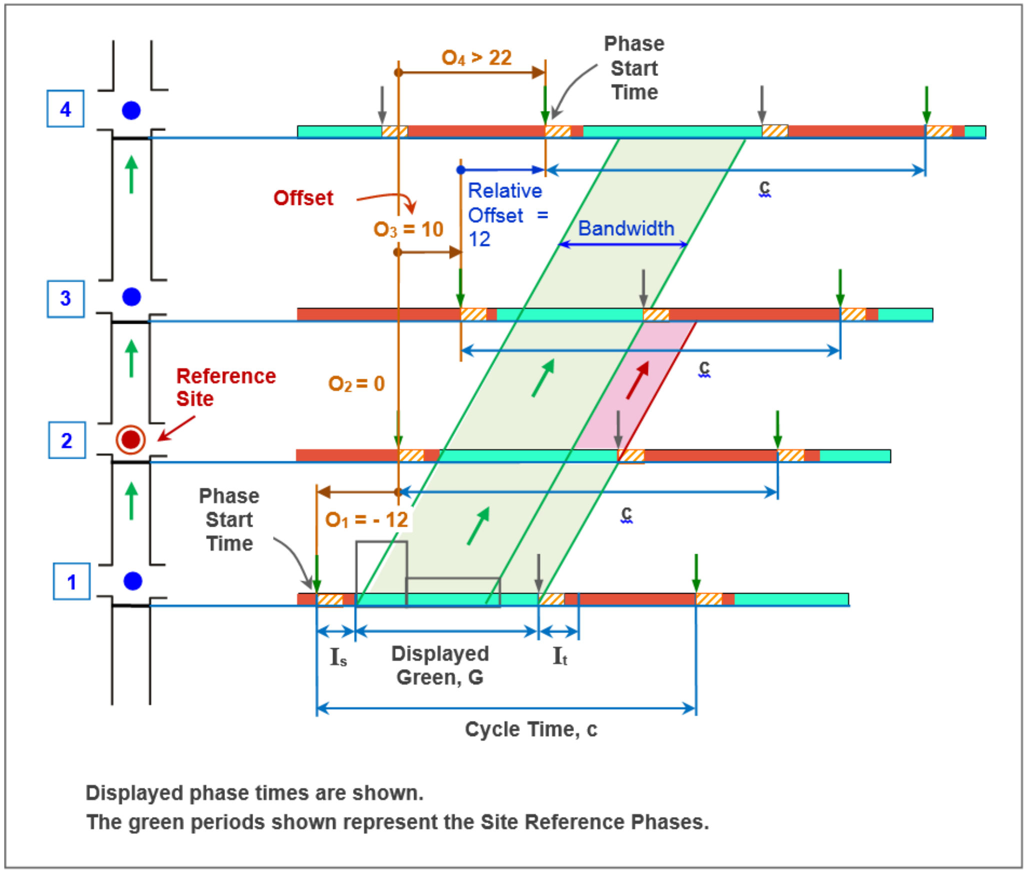
Arrival patterns at downstream lanes

The modelling of PLATOON ARRIVAL PATTERNS at downstream approach lanes takes into account:

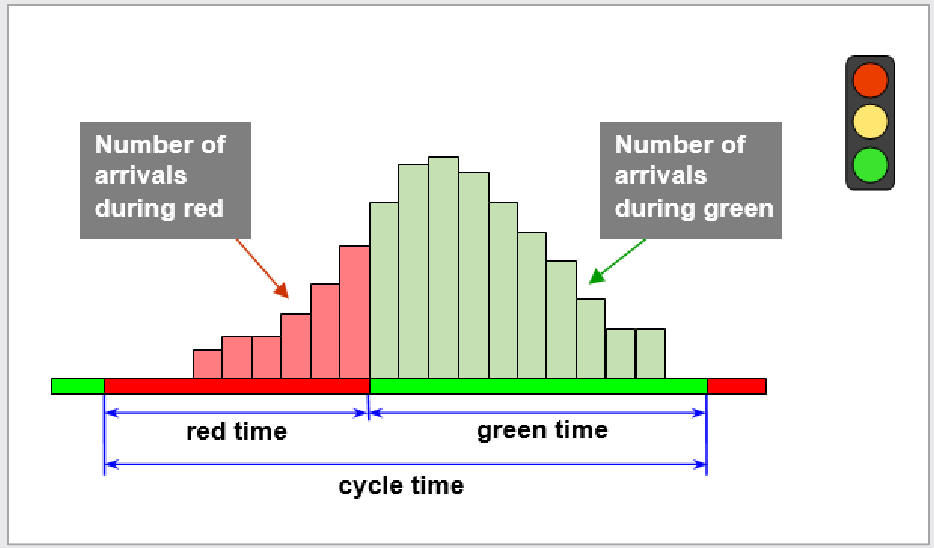
- Platoon Dispersion
- Midblock LANE CHANGES based on matching of upstream and downstream lane flow rates. These are different from lane changes for entry into short lanes included in the model.
- Any midblock inflow and outflow rates (including uniform arrival flow patterns for inflow) implied by turning volume specifications are also taken into account.
- Movement Classes (Light vehicles, Heavy Vehicles, Buses, Large Trucks, etc.) due to different lane use and approach cruise speeds.

The model improves assessment of signal coordination quality and optimisation of signal offsets.

NETWORK TIMING and Platoon Patterns



The **second-by-second arrival patterns** determined by the program as a function of **signal offsets** are used to calculate **Percent Arriving During Green**, P_G and **Platoon Ratio**, P_A for each approach lane for use in performance calculations.



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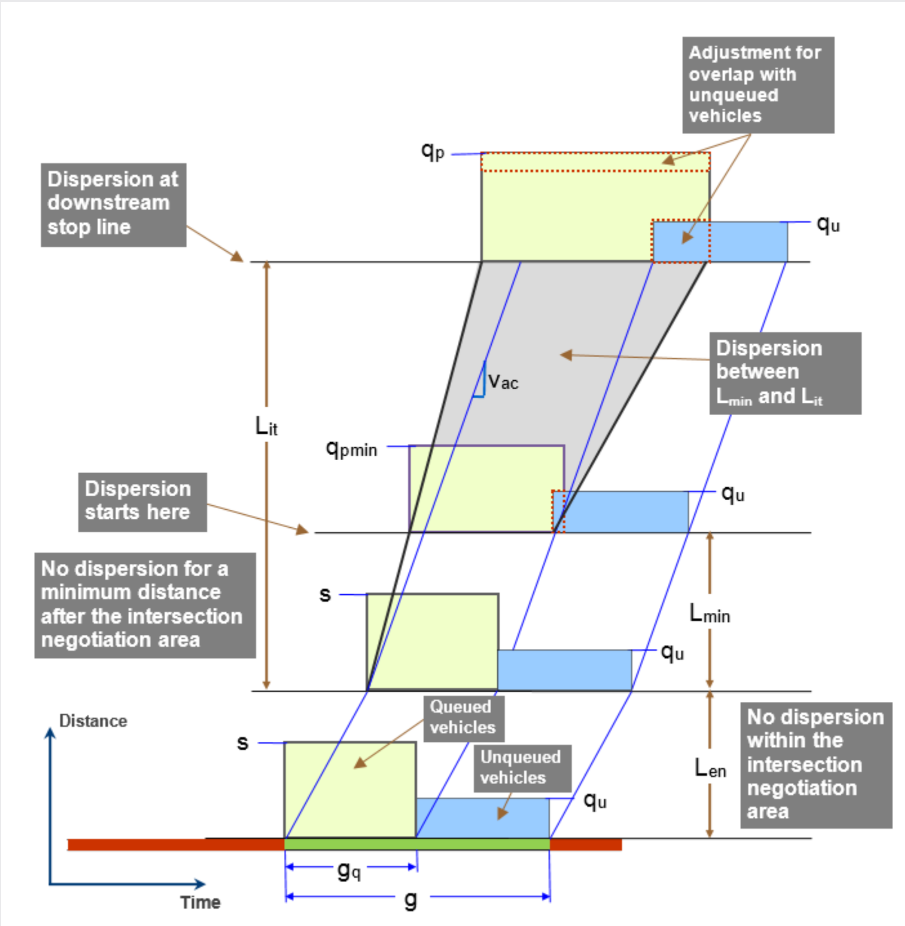
Platoon Dispersion Model

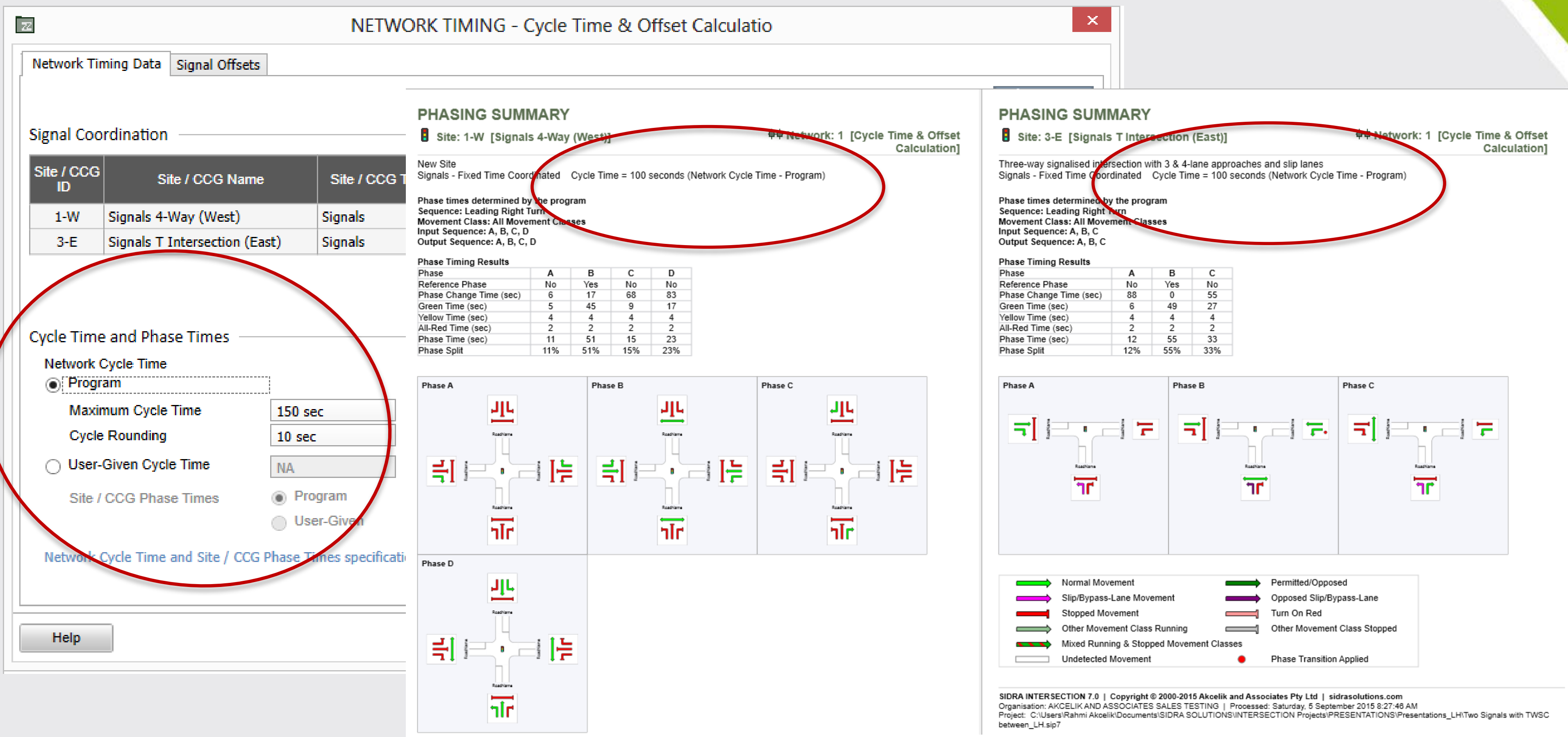


No platoon dispersion in short distances …

	Default	Range	
		min	max
f_{pf}	0.80	0.50	1.50
f_{pmin}	1.00	1.00	1.50
f_{pmax}	1.25	1.00	2.00
L_{min} (m / ft)	60 m	0	200 m
L_{max} (m / ft)	300 m	100 m	2000 m

Maximum platoon dispersion occurs at distance L_{max}.
A platoon factor of f_p = 1.25 means 1.25 increase in platoon time length.

NETWORK SIGNAL TIMING - CYCLE TIME



NETWORK TIMING - Cycle Time & Offset Calculatio

Network Timing Data | Signal Offsets

Signal Coordination

Site / CCG ID	Site / CCG Name	Site / CCG T
1-W	Signals 4-Way (West)	Signals
3-E	Signals T Intersection (East)	Signals

Cycle Time and Phase Times

Network Cycle Time

- (•) Program
  - Maximum Cycle Time: 150 sec
  - Cycle Rounding: 10 sec
- ( ) User-Given Cycle Time: NA

Site / CCG Phase Times: (•) Program ( ) User-Given

Network Cycle Time and Site / CCG Phase Times specificati

Help

PHASING SUMMARY

Site: 1-W [Signals 4-Way (West)] — **Network: 1 [Cycle Time & Offset Calculation]**

New Site
Signals - Fixed Time Coordinated Cycle Time = 100 seconds (Network Cycle Time - Program)

Phase times determined by the program
Sequence: Leading Right Turn
Movement Class: All Movement Classes
Input Sequence: A, B, C, D
Output Sequence: A, B, C, D

Phase Timing Results

Phase	A	B	C	D
Reference Phase	No	Yes	No	No
Phase Change Time (sec)	6	17	68	83
Green Time (sec)	5	45	9	17
Yellow Time (sec)	4	4	4	4
All-Red Time (sec)	2	2	2	2
Phase Time (sec)	11	51	15	23
Phase Split	11%	51%	15%	23%

Phase A | Phase B | Phase C | Phase D

PHASING SUMMARY

Site: 3-E [Signals T Intersection (East)] — **Network: 1 [Cycle Time & Offset Calculation]**

Three-way signalised intersection with 3 & 4-lane approaches and slip lanes
Signals - Fixed Time Coordinated Cycle Time = 100 seconds (Network Cycle Time - Program)

Phase times determined by the program
Sequence: Leading Right Turn
Movement Class: All Movement Classes
Input Sequence: A, B, C
Output Sequence: A, B, C

Phase Timing Results

Phase	A	B	C
Reference Phase	No	Yes	No
Phase Change Time (sec)	88	0	55
Green Time (sec)	6	49	27
Yellow Time (sec)	4	4	4
All-Red Time (sec)	2	2	2
Phase Time (sec)	12	55	33
Phase Split	12%	55%	33%

Phase A | Phase B | Phase C

Normal Movement | Permitted/Opposed
Slip/Bypass-Lane Movement | Opposed Slip/Bypass-Lane
Stopped Movement | Turn On Red
Other Movement Class Running | Other Movement Class Stopped
Mixed Running & Stopped Movement Classes
Undetected Movement | Phase Transition Applied

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NETWORK SIGNAL TIMING - OFFSETS

NETWORK TIMING - Cycle Time & Offset Calculatio

Network Timing Data | Signal Offsets

Quick Input

Signal Offsets

Signal Offsets

- (●) Program
- ( ) User

Routes for Offset Calculation

Move Up | Move Down

	Route ID	Route Name	Offset Priority	Signal Offset Method	Movement Class
☑	1	WB Through	1	Start of Green (Leading)	Light Vehicles
☐	2	EB Through	2	Start of Green (Leading)	Light Vehicles

It is recommended that the first (h
Routes with Unsignalised Sites, o
a single CCG only are not include
NA: The Route has no Movement
implemented.

Setting

Signal Offset Definition

- (●) Offsets (Phase Start)
- ( ) Offsets (Green Start)

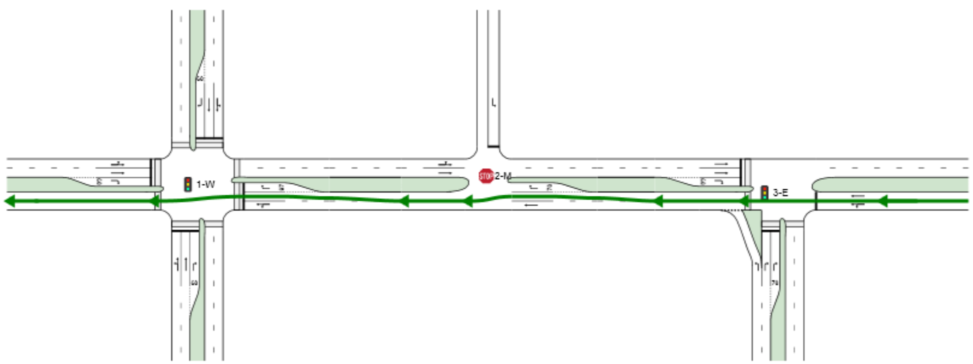
Help

ROUTE LAYOUT

Route: 1 [WB Through]

Network: 1 [Cycle Time & Offset Calculation]

Westbound Through Route



SIGNAL OFFSETS

Network: 1 [Cycle Time & Offset Calculation]

New Network

Offset Definition: Phase Start
Reference Site / CCG: 3-E [Signals T Intersection (East)][1]
Cycle Time (sec): 100

Signal Offsets

Site ID	3-E[1]	1-W
CCG ID (if applicable)	NA	NA
Offset (sec)	0	17
Program / User	P	P
Reference Phase	B	B
Route ID	1	1

Route Offset Calculation Results

Route ID: 1
Route Name: WB Through
Offset Priority: 1
Offset Method: Start of Green (Leading)
Movement Class: Light Vehicles

Site ID	3-E[1]	1-W
Reference Phase	B	B
Offset (sec)	0	17
Calculated offset used (Yes / No)	Y	Y
Approach	E	E
Turn	T1	T1
Stopline Travel Distance (m)	0.0	231.8
Stopline Travel Time (sec)	0.0	16.3
Start Phase of Movement	B	B
Relative Offset (sec)	0	17
Phase Change Time (sec)	0	17
Effective Green Start Time (sec)	9	26
Effective Green Time (sec)	49	45
Green Time Ratio	0.490	0.450
% Arriving During Green	49.0	76.0
Platoon Ratio	1.000	1.688
Equivalent AT	3	5

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Special Movement Classes in Network analysis

Analysis of closely-spaced intersections can be enhanced by using SPECIAL MOVEMENT CLASSES based on User Classes in SIDRA INTERSECTION.

When the Network OD flows are known, external approach movements that continue as turning movements on internal approaches can be treated as Special Movement Classes.

These movements can then be assigned to upstream and downstream lanes according to their downstream destinations. This was found to improve the lane-based modelling of second-by-second platoon patterns further.

Figures given in next few slides

Common Control Groups

Common Control Group (CCG) is used for Sites that form a group of signals controlled by a single signal controller.

This is relevant to the modelling of **paired (closely-spaced) intersections** such as staggered T intersections, freeway interchanges, intersections with median storage and fully signalised roundabouts.

All Sites in a Common Control Group will have the **same phase sequence** with **same Phase Times**, and there will be a **single Offset** relevant to the group.

Figures given in next few slides

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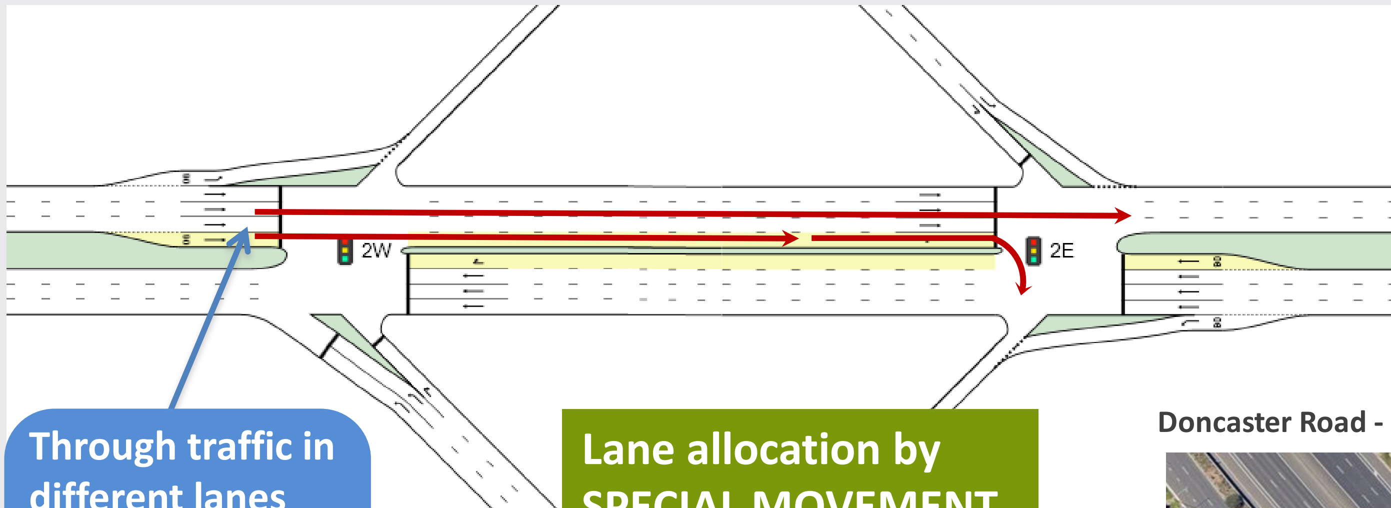
Network Example: Freeway Diamond Interchange

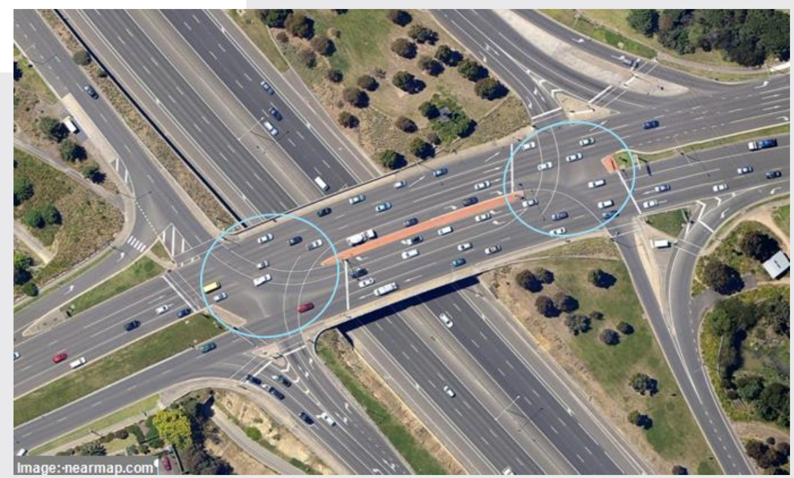


Through traffic in different lanes have different destinations downstream

Lane allocation by SPECIAL MOVEMENT CLASSES for turning movements

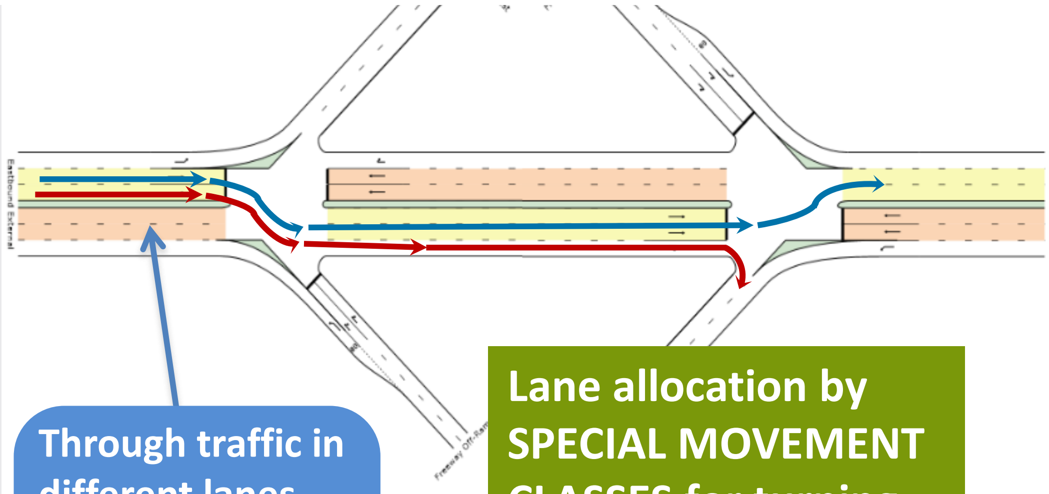
Common Control Group

Doncaster Road - Eastern Freeway, Melbourne



Network Examples: Diverging Diamond Interchange

Diverging Diamond Interchange

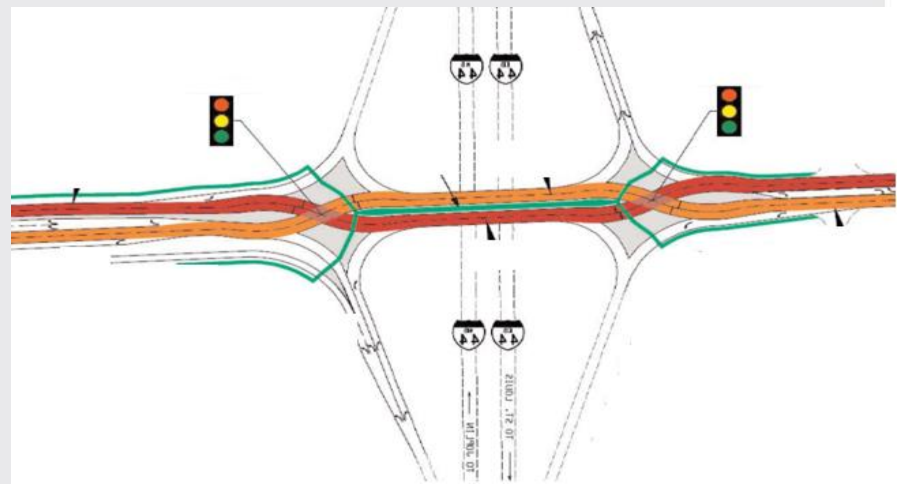


Through traffic in different lanes have different destinations downstream

Lane allocation by SPECIAL MOVEMENT CLASSES for turning movements

Templates will be available

Common Control Group



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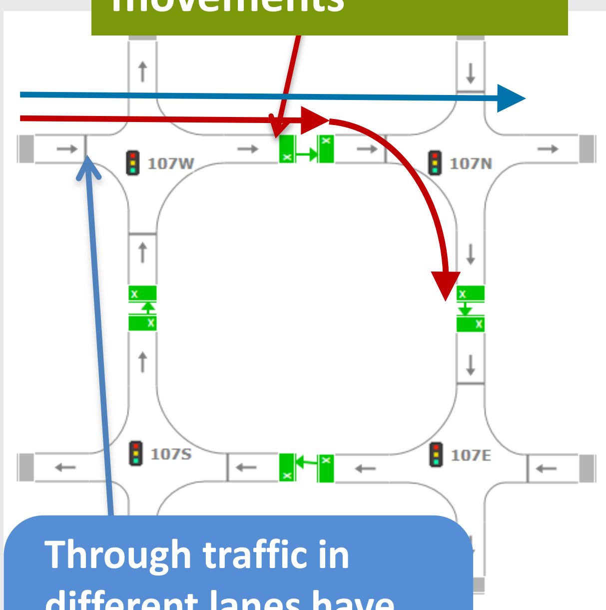
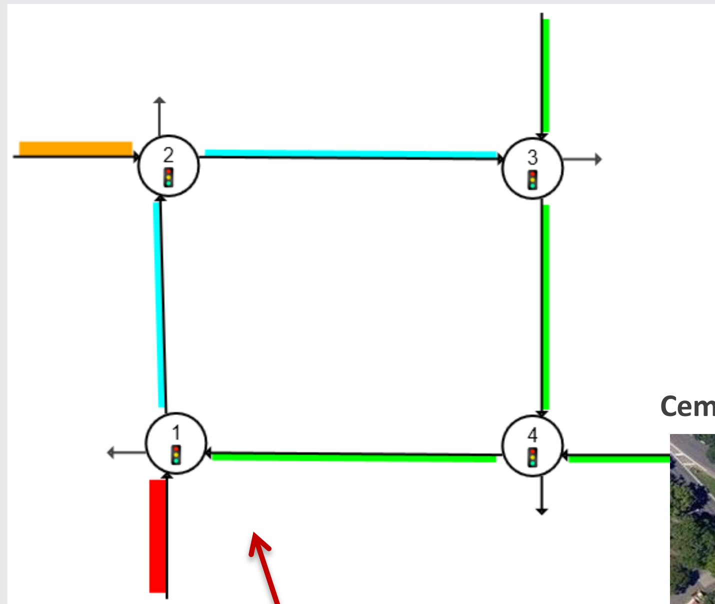
Network Example: Fully Signalised Roundabout

Lane allocation by SPECIAL MOVEMENT CLASSES for turning movements



Through traffic in different lanes have different destinations downstream



Network Displays

Common Control Group

Cemetery Road East - Swanston Street, Melbourne

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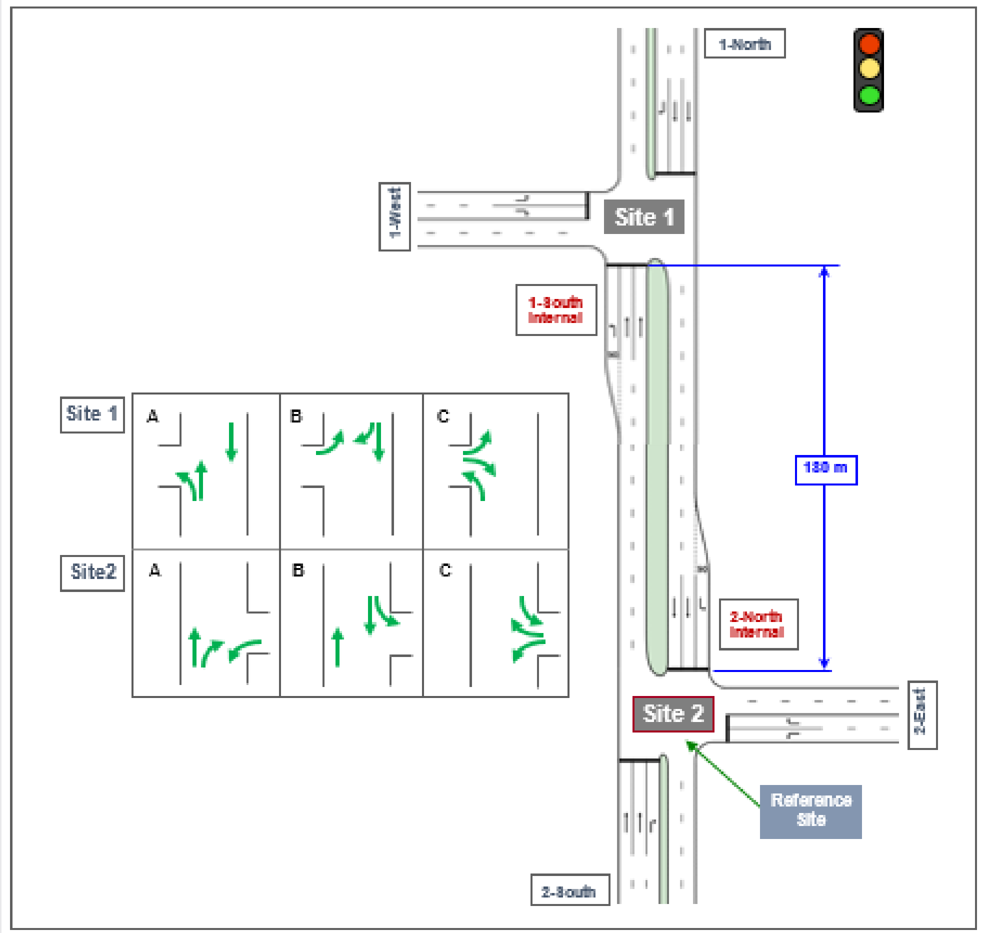
Network Example : Staggered T intersections

ARRB Conference 2014 paper

A detailed example is presented using various analysis scenarios to investigate basic aspects of the lane-based network model in relation to signal platooning.

Staggered T intersections with 180 m distance between them.

Detailed description is presented in the ARRB Conference 2014 paper (available for download on www.sidrasolutions.com/Resources/Articles).



Analysis Scenarios

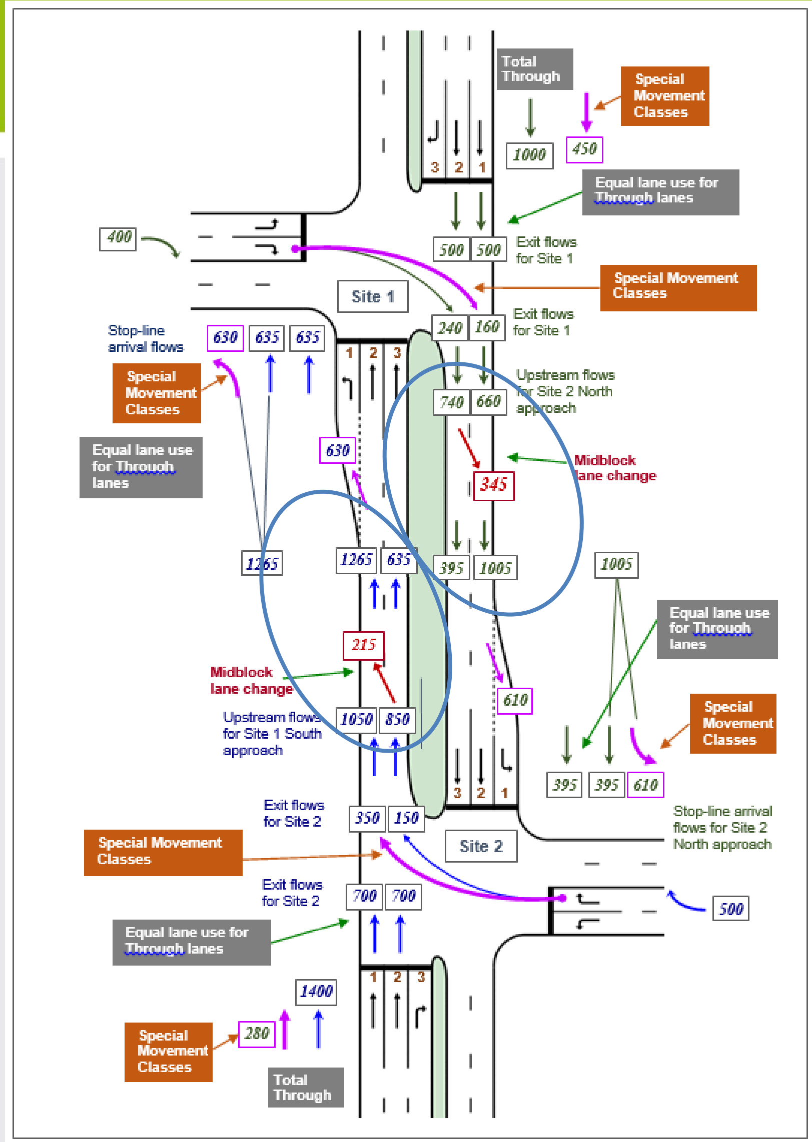
Network OD flows that match the Site OD flows perfectly are used for analysing differences between **analysis scenarios with and without knowledge of Network OD flows**.

The analysis scenarios are used to investigate the differences between **signal platooning** and the resulting **performance estimates** according to the **assumptions about approach lane use and exit lanes chosen** in departing from an intersection.

The differences between the analysis scenarios are identified according to differences **in midblock lane change implications** for internal approach lanes.

Analysis Scenario (i) with Special Movement Classes

- **Network OD flows are known** in addition to the Site OD flows.
- **Lane Movement Flow Proportions for Site 1 West Right and Site 2 East Right movements are specified** based on known Network OD flows.
- **Equal lane use** for all Through approach lanes. This results in **implied midblock lane changes.**



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Lane results

Comparison of results for Through LANES on Site 1 South internal (Northbound) approach

Approach Lane	Arrival Flow (veh/h)	Capacity (veh/h)	Degree of Saturation (v / c)	Per cent Arriving During Green (%)	Platoon Ratio	Average Delay (s)	95th %ile Back of Queue (m)
Analysis Scenario (i) with Special Movement Classes for downstream turns							
South Lane 2	635	988	0.643	86.5%	1.664	5.2	65
Lane 3	635	988	0.643	75.8%	1.457	10.7	102
Analysis Scenario (ii) without Special Movement Classes							
South Lane 2	635	988	0.643	68.0%	1.227	16.0	132
Lane 3	635	988	0.643	75.8%	1.457	10.7	102

Concluding Remarks

The **Lane-based** platoon model used in SIDRA INTERSECTION differs from the use of "**links**" or "**lane groups**“ in traditional network models.

The new lane-based method derives second-by-second downstream **lane arrival patterns** from upstream **lane departure patterns** with **midblock lane changes**.

In the traditional network models using **links** or **lane groups**:

- individual lane conditions are aggregated
- insufficient information about queue lengths, lane blockage probabilities, backward spread of queues, and so on as these need lane level of detail.

Concluding Remarks

A complete **LANE-BASED** model with

- lane-based **input**
- lane-based **capacity and performance calculations**, and
- lane-based **output**

as used in SIDRA INTERSECTION is particularly important in evaluating

- **closely-spaced** intersections
- **high demand flows**
- cases where vehicles have **limited opportunities for lane changing** between intersections.

END OF PRESENTATION