

Signal platoon patterns by approach lane use and movement class

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Signal platoon patterns by approach lane use and movement class

The presentation:

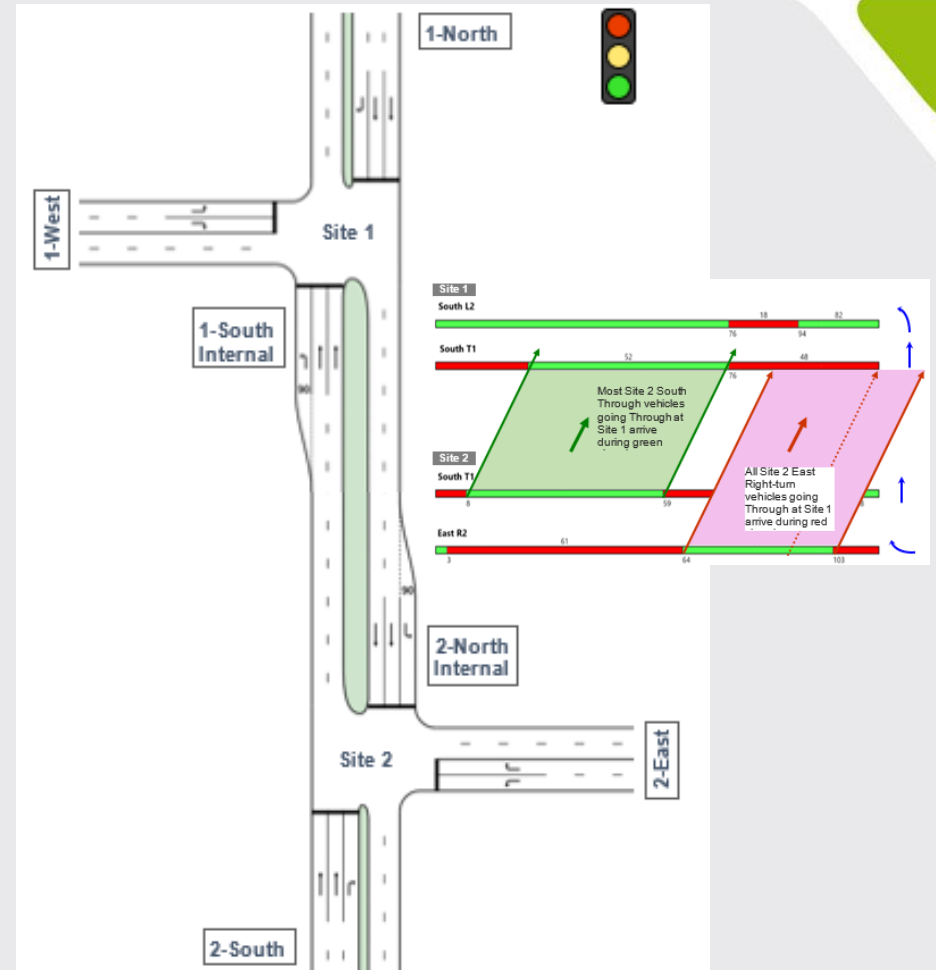
Basic features of the lane-based platoon model

- Lane-based model
- Arrival and Departure patterns
- Signal platoon model (including platoon dispersion)

Movement Classes

Example : Staggered T intersection

Conclusions



Basic features of the lane-based platoon model

“Lane-based” platoon model as opposed to the use of “links” or “lane groups”:

A new analytical **lane-based** method for determining platoon patterns at closely-spaced signalised intersections.

Developed for the SIDRA INTERSECTION software.

Traditional network models use **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.

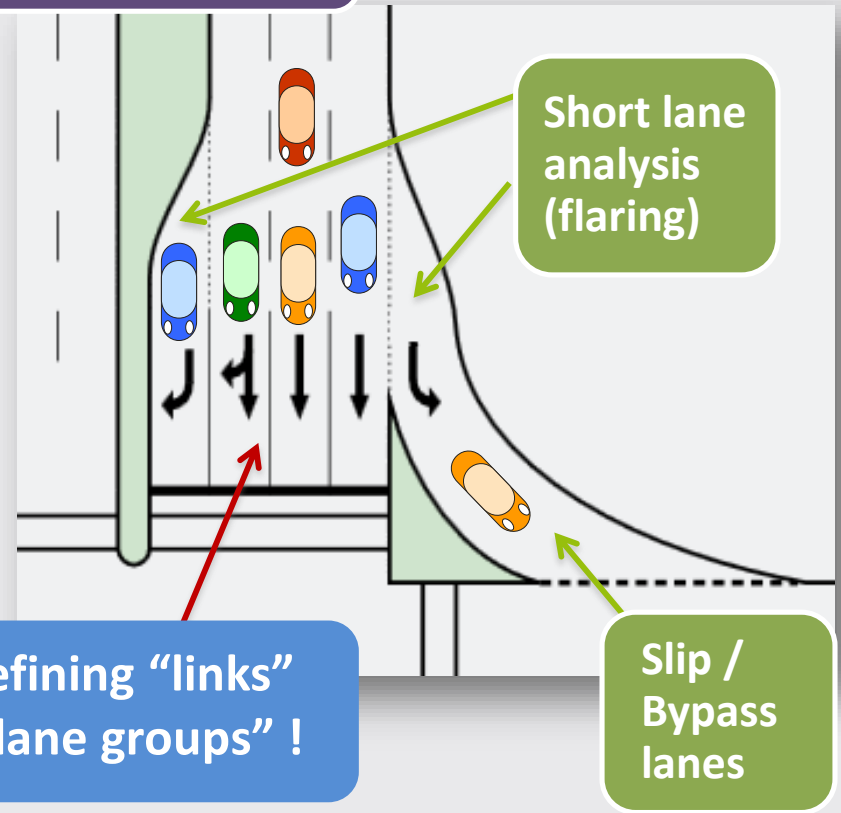
Lane-based model for intersections

LANE-BASED MODEL

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

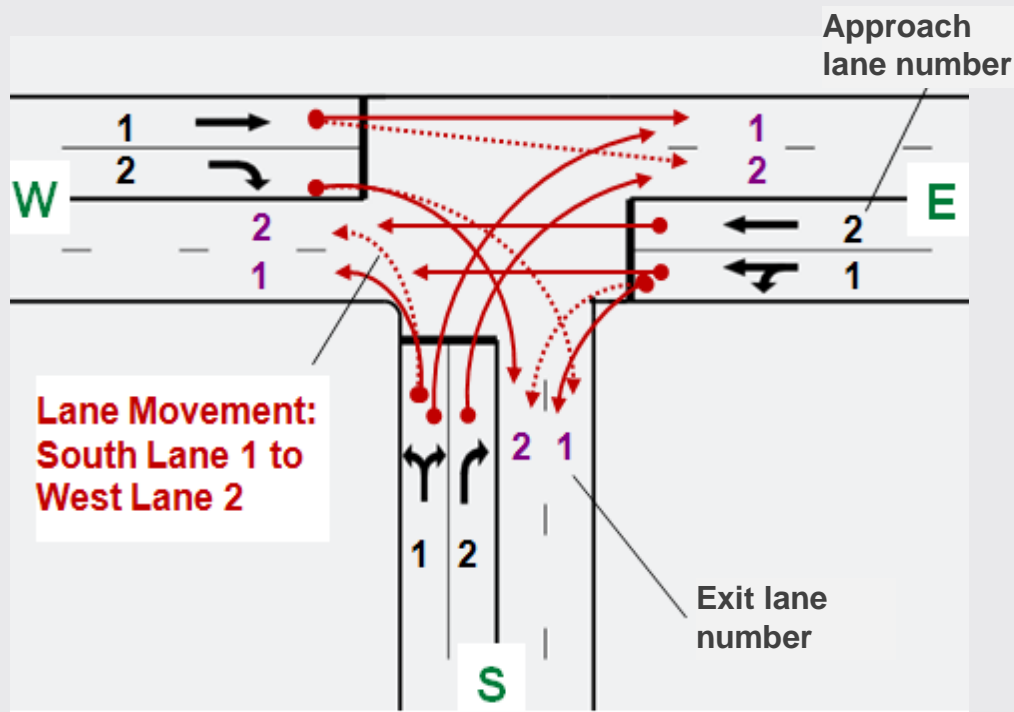
- **General:** Unequal lane flows, de facto exclusive lanes, short lanes, slip/bypass lanes (give-way/yield, continuous, signals) .
- **Roundabouts:** Circulating lane use; Dominant and subdominant lanes.
- **NETWORK Model** (lane queues, lane blockage, signal platoon arrival and departure patterns).

Individual lanes have different characteristics

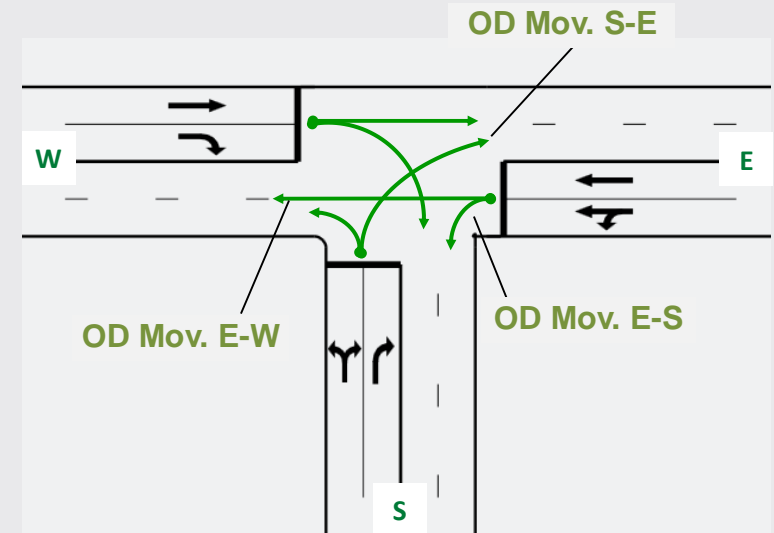


Lane-based model for NETWORKS

Lane Movements



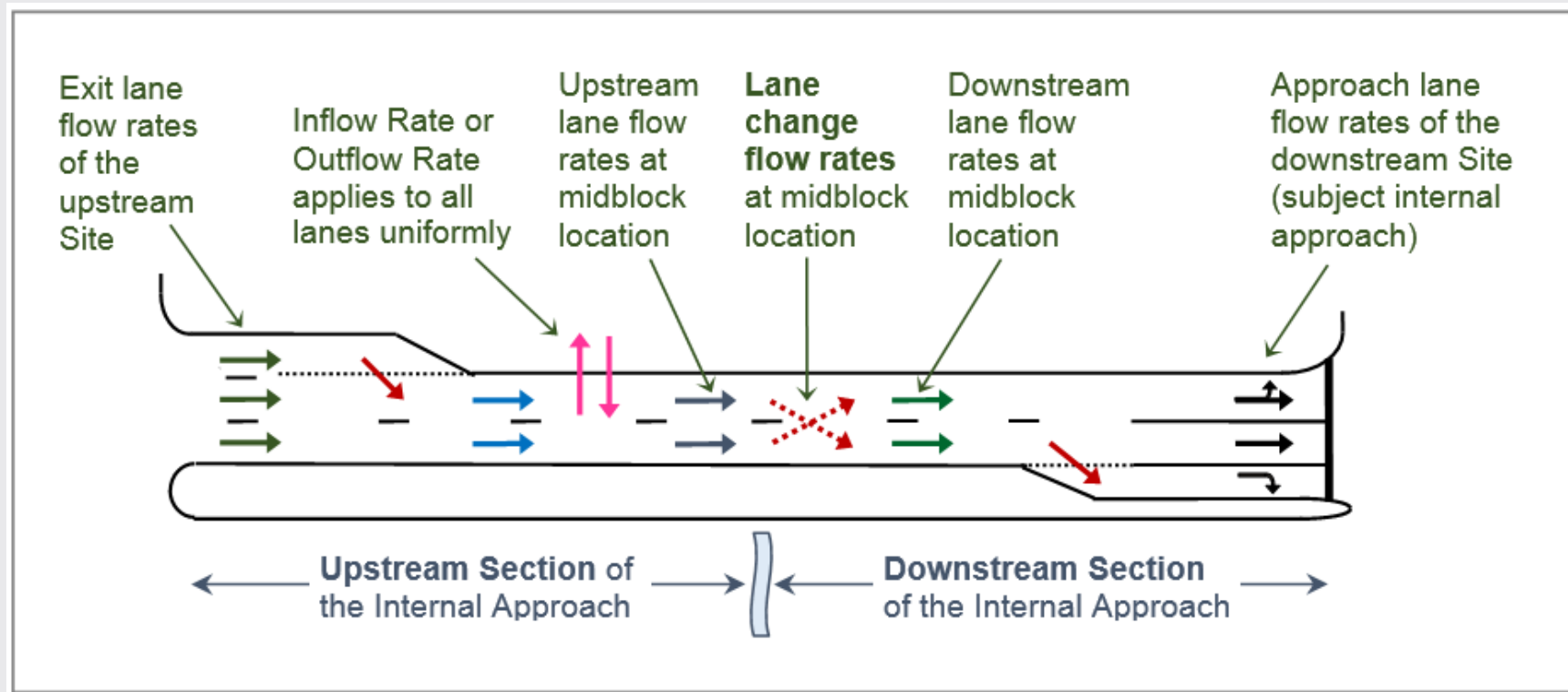
Origin – Destination (OD) Movements



Lane-based model for NETWORKS

Lane Changes

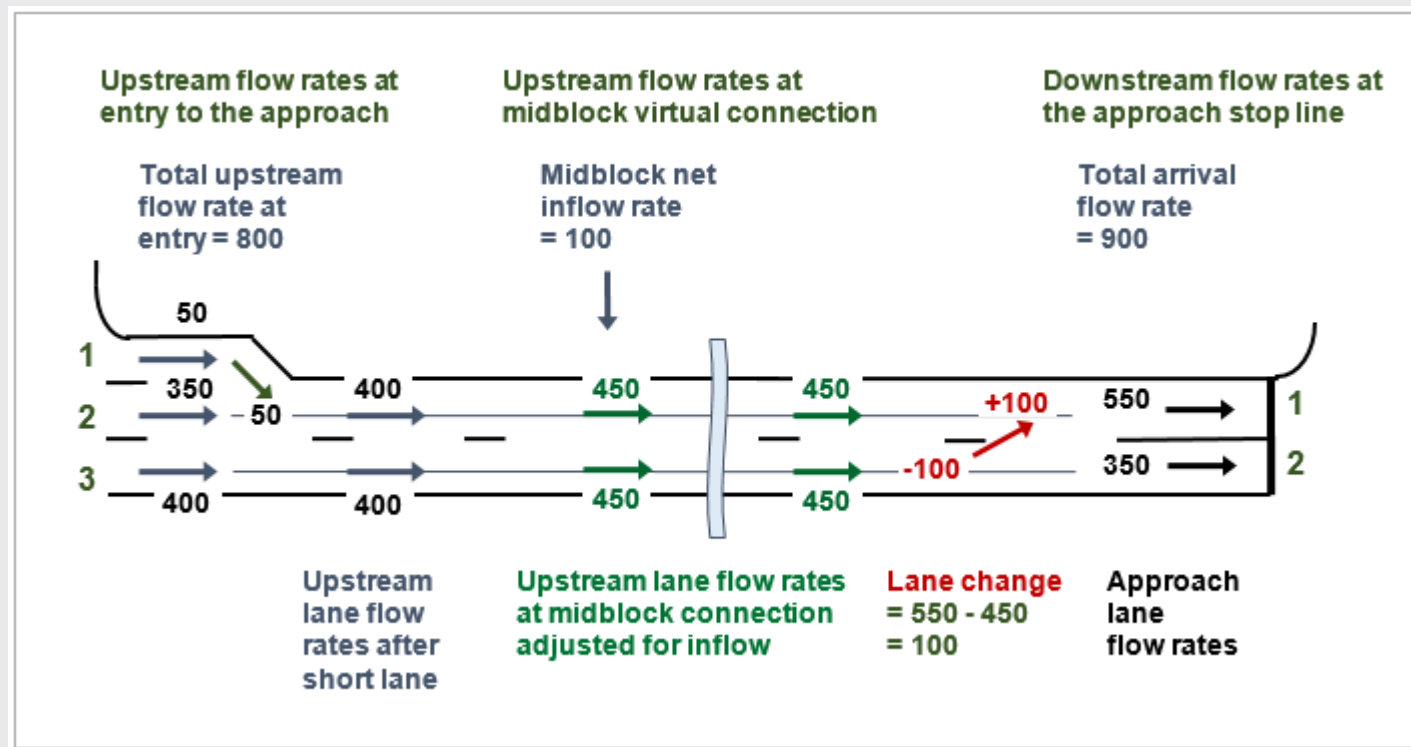
Second-by-second platoon patterns move accordingly



Lane-based model for NETWORKS

Example with Net Inflow

Second-by-second platoon patterns move accordingly



Lane-based model for networks

Lane-based model is particularly important in evaluating

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

The new lane-based method derives second-by-second downstream **arrival patterns** from upstream **departure patterns** taking into account arrival flow and saturation flow rates of individual lanes at both upstream and downstream intersections.

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 arrival flows** at downstream lanes due to **capacity constraint** at oversaturated upstream lanes
- **lane movement flow proportions** at the upstream intersection.



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.



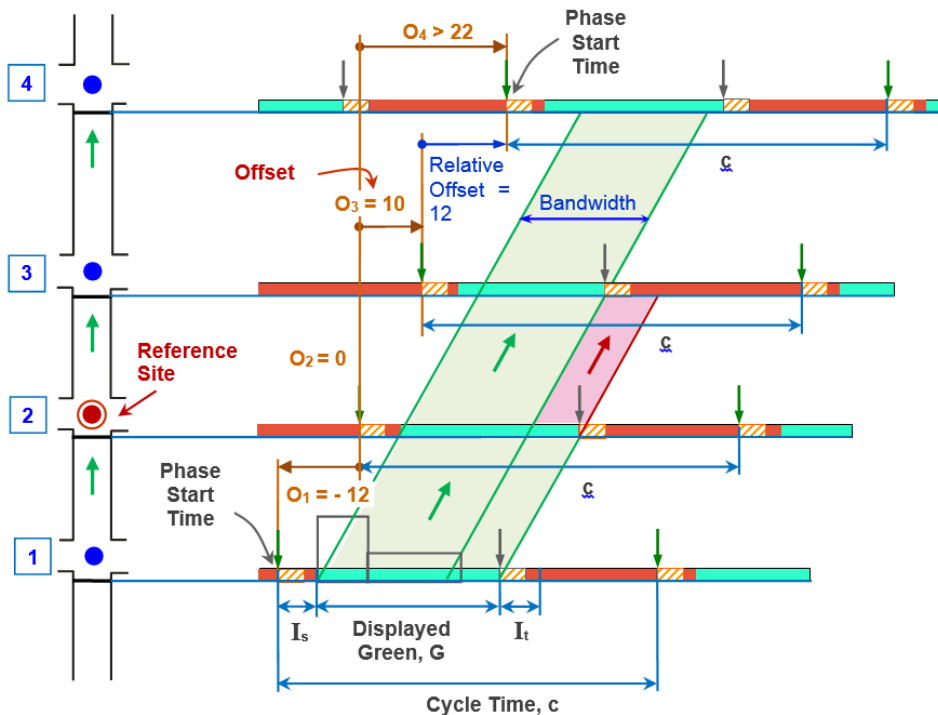
Arrival patterns at downstream lanes

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.

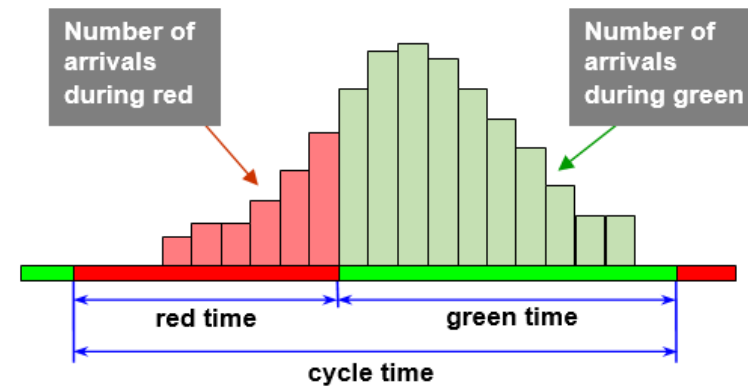
The model improves **assessment of signal coordination quality** and optimisation of signal offsets.

NETWORK TIMING and Platoon Patterns



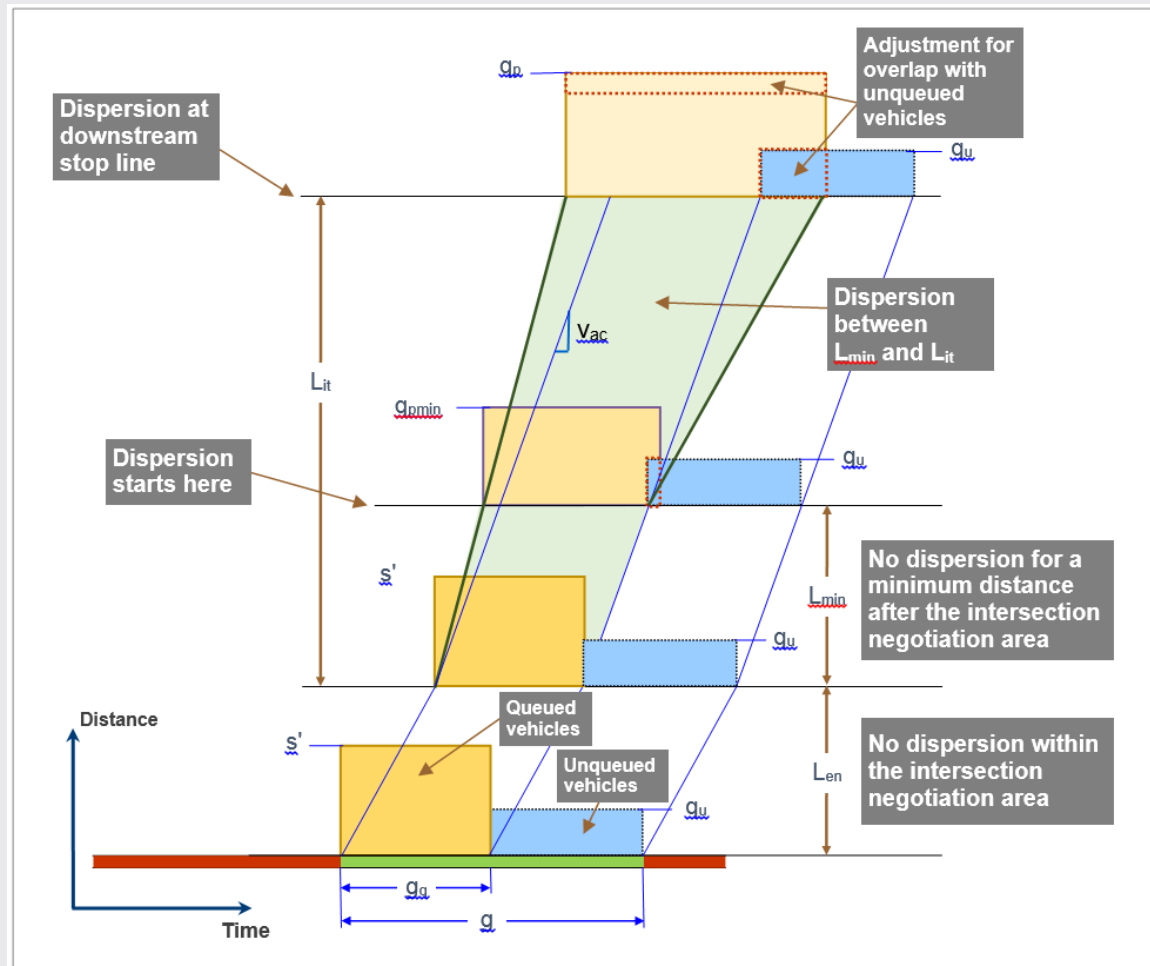
Displayed phase times are shown.
The green periods shown represent the Site Reference Phases.

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.



Arrival patterns at downstream lanes

Platoon
Dispersion:
a unique
model
(optional)



Movement Classes in SIDRA INTERSECTION

Movement Classes

Light Vehicles

Heavy Vehicles

Buses

Bicycles

Large Trucks

Trams /Light rail

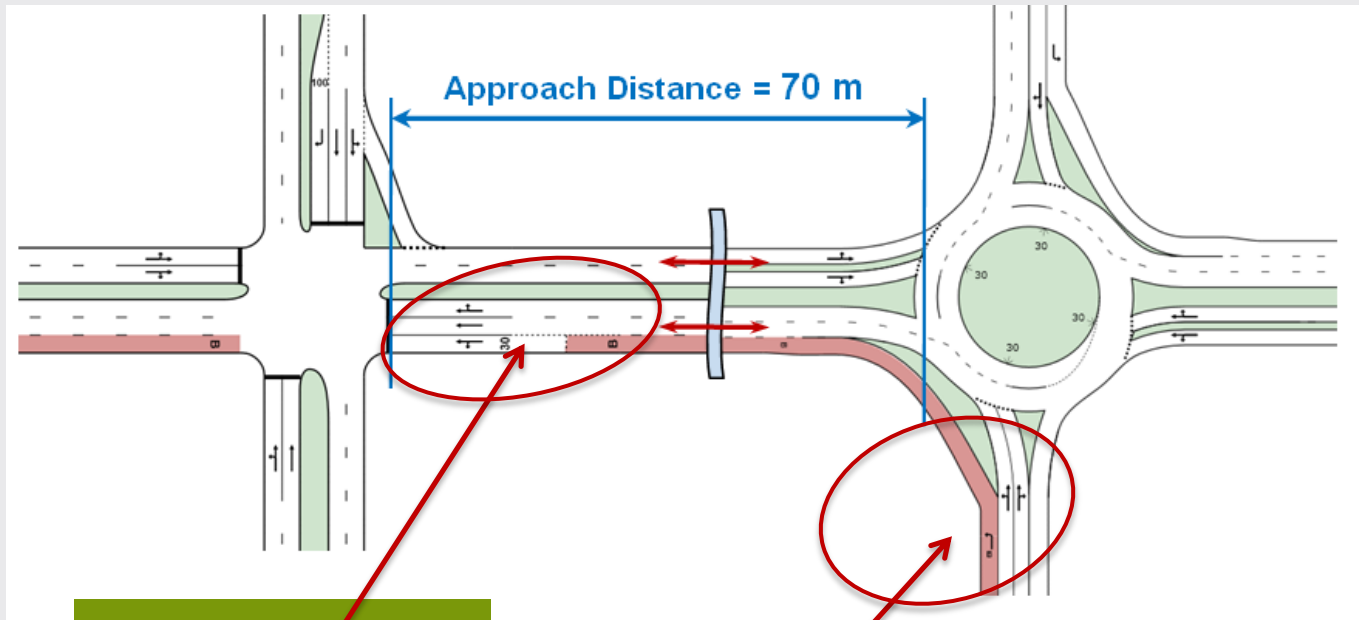
User Classes

(for special treatment)



Network Example: Signals and Roundabout with Bus lane

SIDRA INTERSECTION Training Workshop Example



Two-segment lane

BUS SLIP (BYPASS) LANE at roundabout - other traffic use the roundabout entry lane



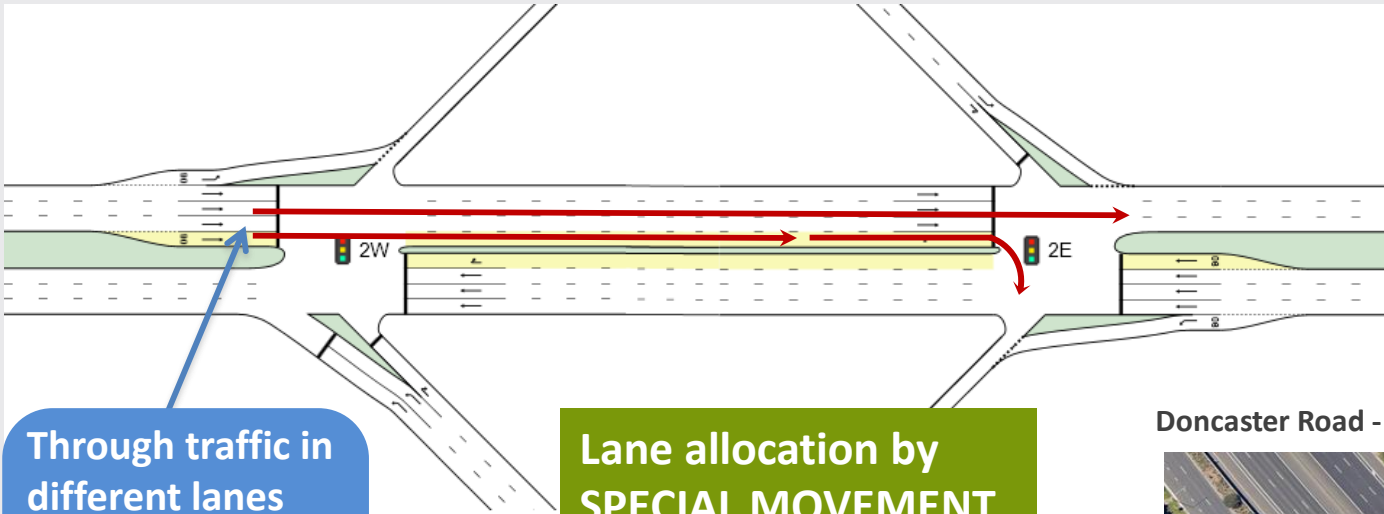
Special Movement Classes in Network analysis

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.

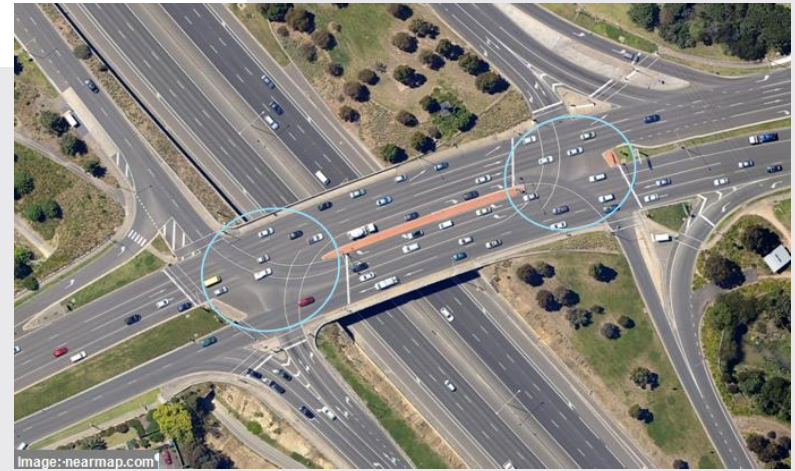
Network Example: Freeway Diamond Interchange



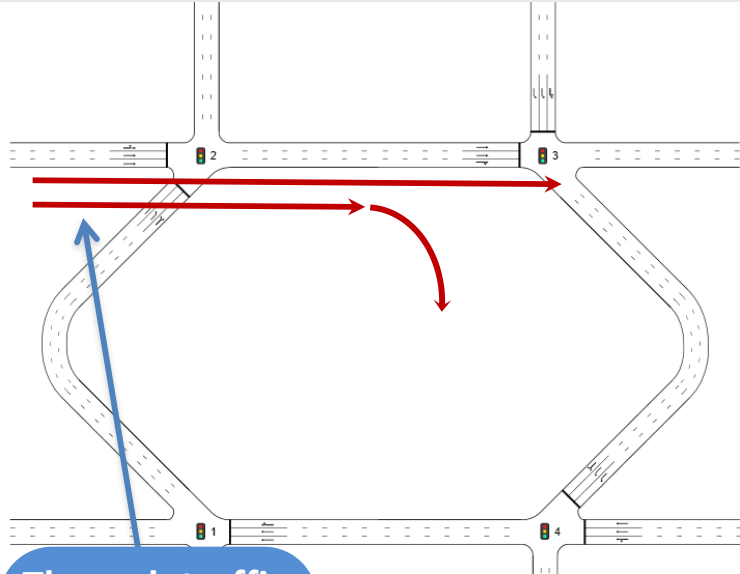
Through traffic in different lanes have different destinations downstream

Lane allocation by SPECIAL MOVEMENT CLASSES for turning movements

Doncaster Road - Eastern Freeway, Melbourne

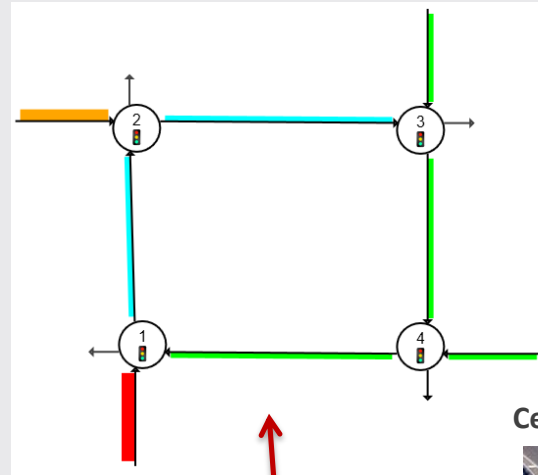


Network Example: Fully Signalised Roundabout



Through traffic in different lanes have different destinations downstream

Lane allocation by SPECIAL MOVEMENT CLASSES for turning movements



Network Displays

Cemetery Road East - Swanston Street, Melbourne



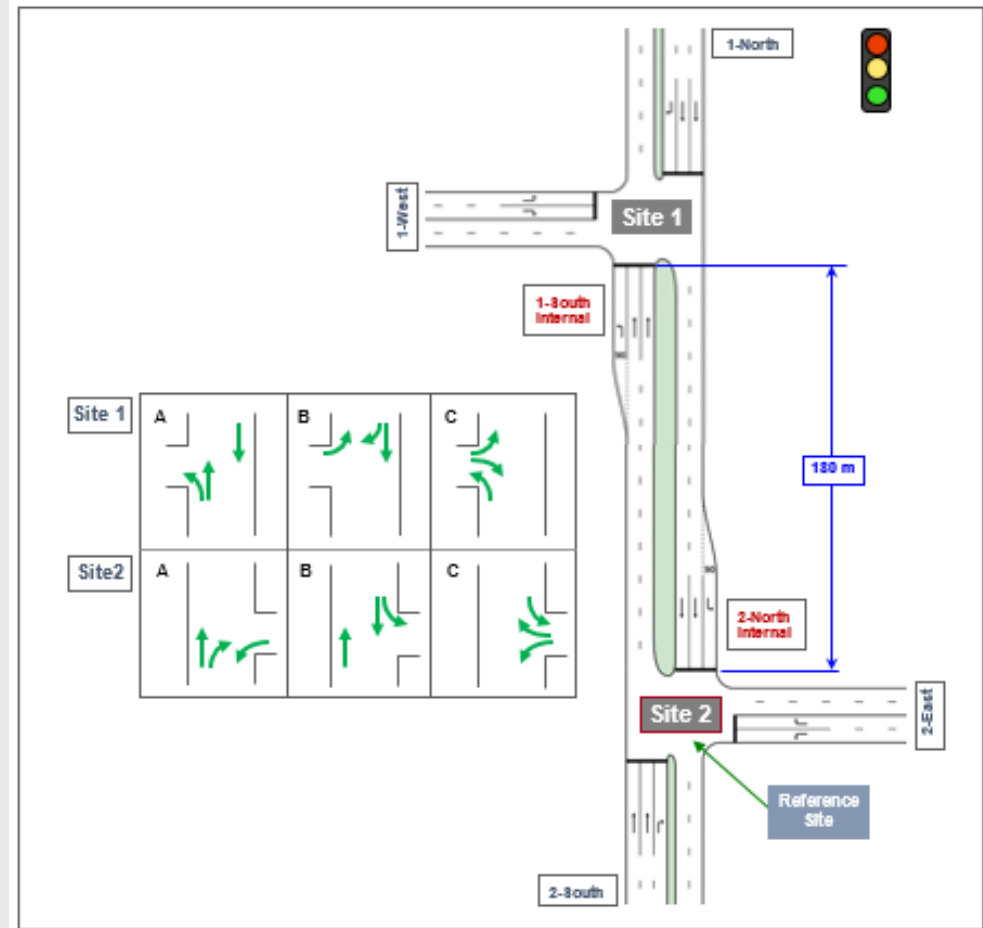
Network Example : Staggered T intersections

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.

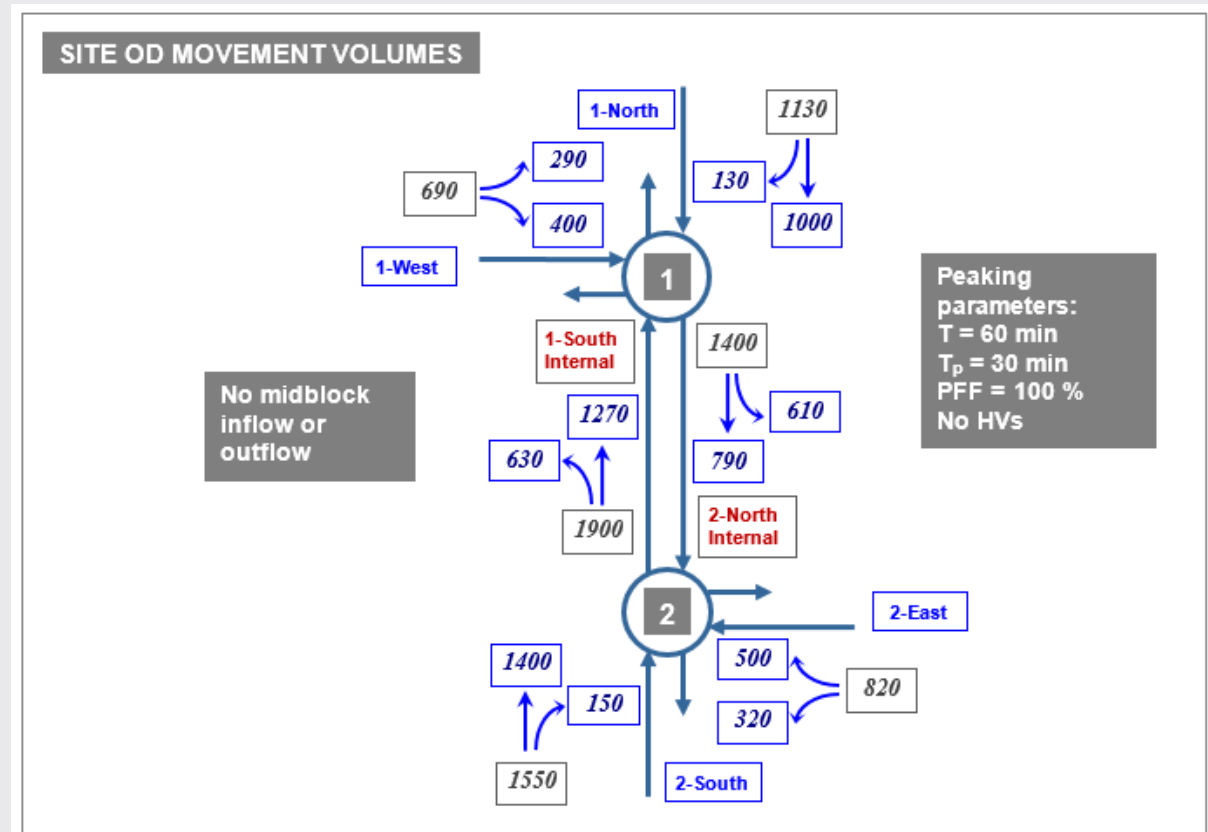
Detailed description is presented in the **ARRB Conference 2014** paper (available for download on www.sidrasolutions.com/Resources/Articles).



Site OD flows and Network OD flows

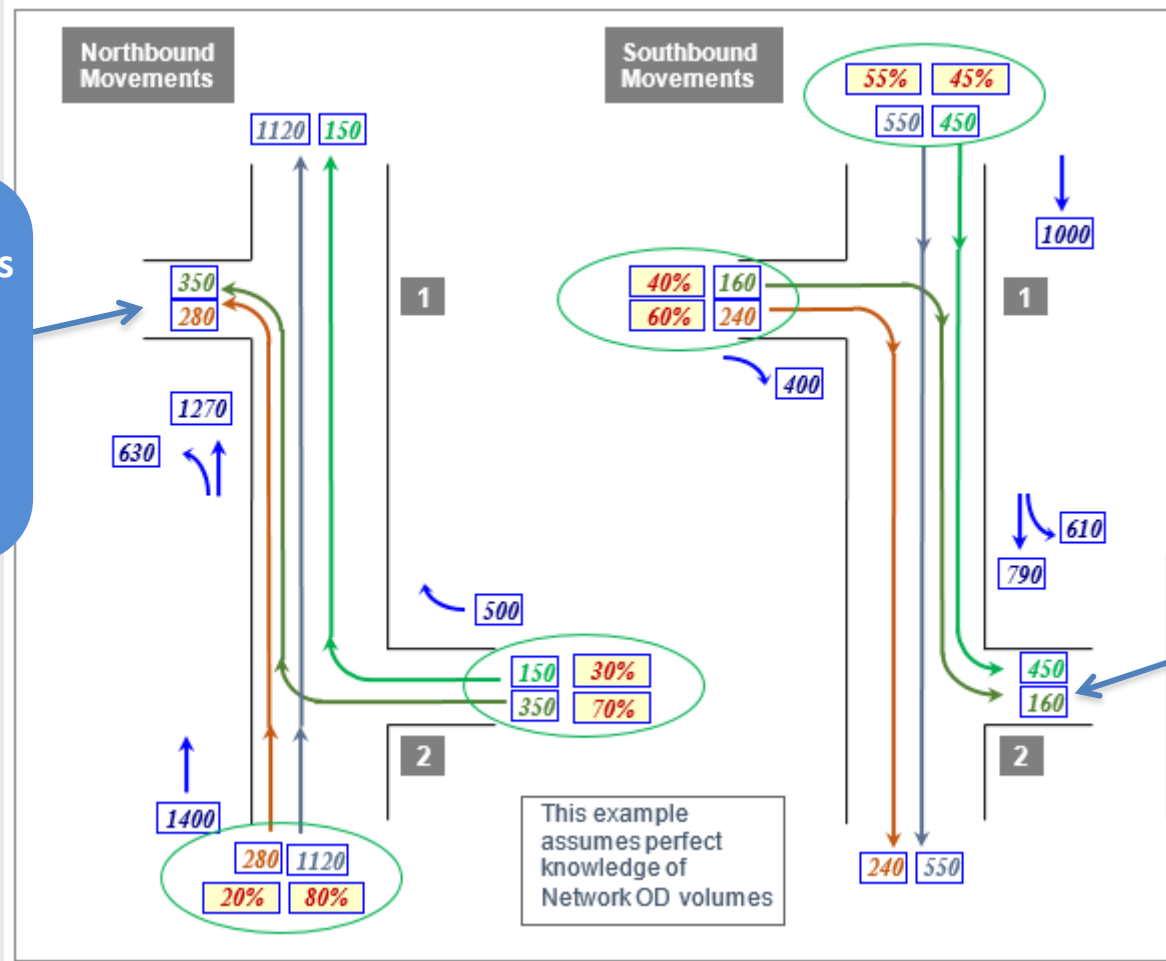
Site Origin - Destination (OD) flows (intersection turning volumes) are used as network flow input by the software.

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**.



Network OD flows

Downstream turning movements treated as Special Movement Classes (**Special Turns LV** and **Special Turns HV**)



Downstream turning movements treated as Special Movement Classes (**Special Turns LV** and **Special Turns HV**)

Network Example : Staggered T intersections

Lane Disciplines

Special Movement Classes (Special Turns LV and Special Turns HV) are allocated to specific lanes

Approach Selector

2 - South

Legend: Lane Editor

- Approach Lane
- Exit Lane
- Selected Lane/Island
- Strip Island/Short Lane
- Selected Movement Class
- Other Movement Class

Show Lane Disciplines by: All Movement Classes

Lane Editor

South Lane 1

South Approach Lane 1

Lane Disciplines

Full-Length Lane	From South to Exit:	N	E
		T1	R2
Light Vehicles (LV)		<input checked="" type="checkbox"/>	<input type="checkbox"/>
Heavy Vehicles (HV)		<input checked="" type="checkbox"/>	<input type="checkbox"/>
Special Turns LV (SL)		<input checked="" type="checkbox"/>	<input type="checkbox"/>
Special Turns HV (SH)		<input checked="" type="checkbox"/>	<input type="checkbox"/>

Approach Selector

2 - South

Legend: Lane Editor

- Approach Lane
- Exit Lane
- Selected Lane/Island
- Strip Island/Short Lane
- Selected Movement Class
- Other Movement Class

Show Lane Disciplines by: All Movement Classes

Lane Editor

South Lane 2

South Approach Lane 2

Lane Disciplines

Full-Length Lane	From South to Exit:	N	E
		T1	R2
Light Vehicles (LV)		<input checked="" type="checkbox"/>	<input type="checkbox"/>
Heavy Vehicles (HV)		<input checked="" type="checkbox"/>	<input type="checkbox"/>
Special Turns LV (SL)		<input checked="" type="checkbox"/>	<input type="checkbox"/>
Special Turns HV (SH)		<input checked="" type="checkbox"/>	<input type="checkbox"/>

Approach Selector

2 - East

Legend: Lane Editor

- Approach Lane
- Exit Lane
- Selected Lane/Island
- Strip Island/Short Lane
- Selected Movement Class
- Other Movement Class

Show Lane Disciplines by: All Movement Classes

Lane Editor

East Lane 2

East Approach Lane 2

Lane Disciplines

Full-Length Lane	From East to Exit:	S	N
		L2	R2
Light Vehicles (LV)		<input type="checkbox"/>	<input checked="" type="checkbox"/>
Heavy Vehicles (HV)		<input type="checkbox"/>	<input checked="" type="checkbox"/>
Special Turns LV (SL)		<input type="checkbox"/>	<input checked="" type="checkbox"/>
Special Turns HV (SH)		<input type="checkbox"/>	<input checked="" type="checkbox"/>

Approach Selector

2 - North Internal

Legend: Lane Editor

- Approach Lane
- Exit Lane
- Selected Lane/Island
- Strip Island/Short Lane
- Selected Movement Class
- Other Movement Class

Show Lane Disciplines by: All Movement Classes

Lane Editor

North Lane 1

North Approach Lane 1

Lane Disciplines

Short Lane	From North to Exit:	E	S
		L2	T1
Light Vehicles (LV)		<input type="checkbox"/>	<input type="checkbox"/>
Heavy Vehicles (HV)		<input type="checkbox"/>	<input type="checkbox"/>
Special Turns LV (SL)		<input checked="" type="checkbox"/>	<input type="checkbox"/>
Special Turns HV (SH)		<input checked="" type="checkbox"/>	<input type="checkbox"/>

Analysis Scenarios

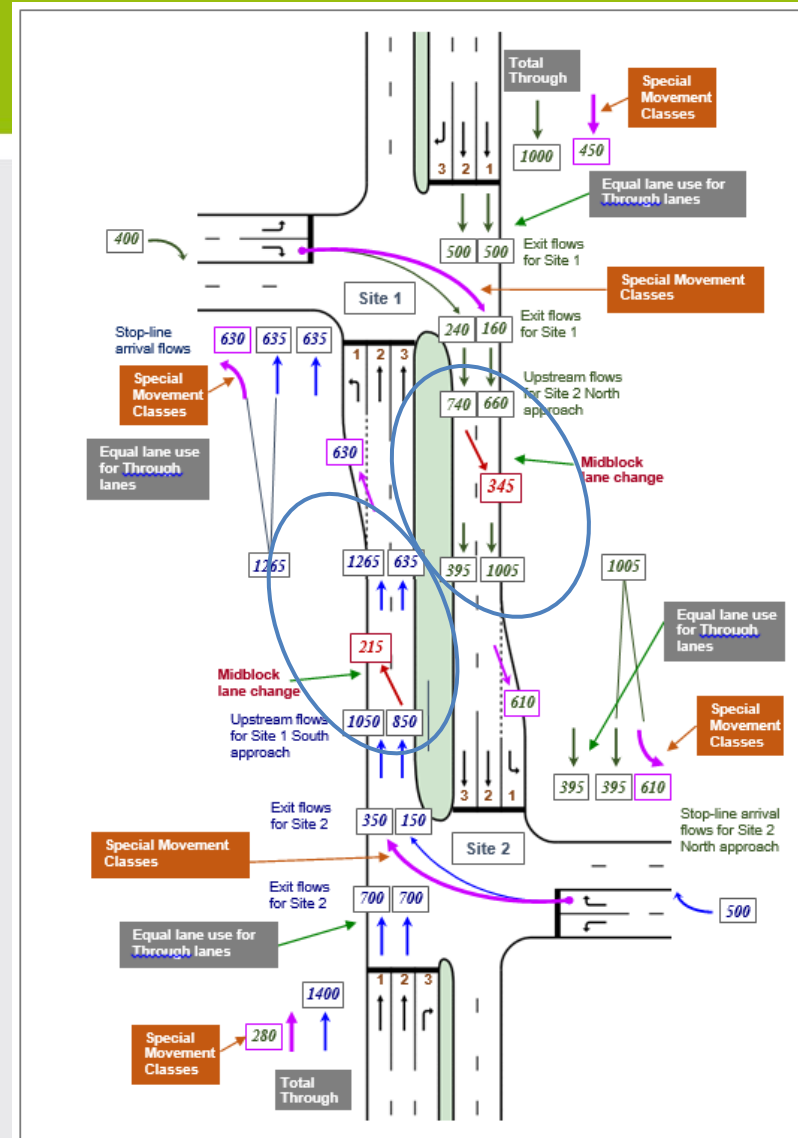
Various analysis scenarios can be considered to investigate the differences between signal platooning and the resulting performance estimates according to the assumptions about approach lane use and exit lanes chosen in departing from an intersection.

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

Many analysis scenarios are possible considering different lane use patterns, Special Movement Class use, and Lane Movement Flow Proportions. The ARRB Conference 2014 paper was limited to three analysis scenarios. Scenario (ii) of the ARRB paper and Scenario (i) with Special MCs are given below.

Analysis Scenario (i) with Special Movement Classes

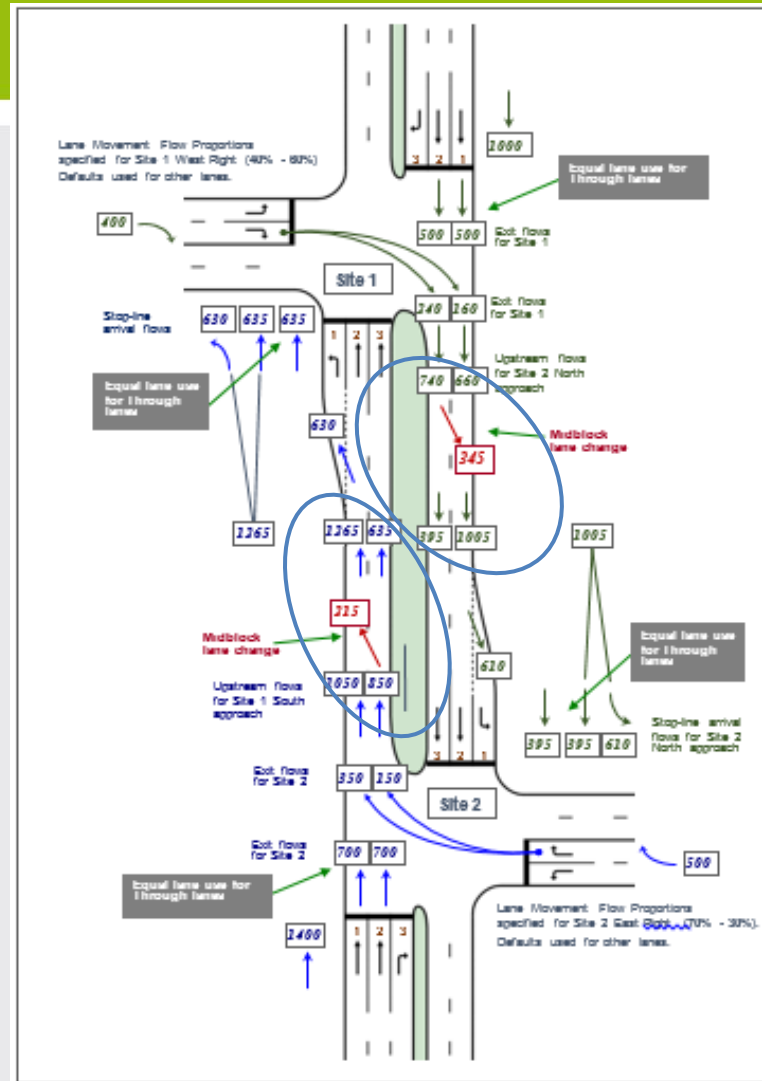
- Network OD flows are known in addition to the Site OD flows.
- Lane Movement Flow Proportions for Site 1 West Right and Site 2 East Right movements are specified based on known Network OD flows
- Equal lane use for all Through approach lanes. This results in implied midblock lane changes.



ARRB Conference 2014 paper

Analysis Scenario (ii)

- **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.**



Analysis results for the example

In the next three slides, results are given for:

- **Scenario (i) with Special Movement Classes** and
- **Scenario (ii) without Special Movement Classes**
(as in the ARRB Conference 2014 paper) are.

The purpose of comparison is to test the effect of modelling
with and without Special Movement Classes

Detailed tables for other scenario comparisons are presented in
the ARRB Conference 2014 paper (available for download on
www.sidrasolutions.com/Resources/Articles).

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

Movement results

Comparison of results for **Left and Through MOVEMENTS**
on Site 1 South internal (Northbound) approach

Movement	Arrival Flow (veh/h)	Degree of Saturation (v / c)	Percent Arriving During Green (%)	Platoon Ratio	Average Delay (s)	95th %ile Back of Queue (m)
Analysis Scenario (i) with Special Movement Classes for downstream turns						
Left	630	0.425	88.1%	1.074	6.0	40
Thru	1270	0.643	81.1%	1.560	8.0	102
Analysis Scenario (ii) without Special Movement Classes						
Left	630	0.425	89.0%	1.085	5.9	37
Thru	1270	0.643	69.8%	1.342	13.4	132

Intersection results

Comparison of results for Site 1

(Cycle Time = 100, Phase Times: 57, 13, 30 for both Scenarios)

Arrival Flow (veh/h)	Degree of Saturation (v / c)	Average Delay (s)	95th %ile Back of Queue (m)	Total Operating Cost (\$/year)	Total CO ₂ Emission (kg/year)
Analysis Scenario (i) with Special Movement Classes for downstream turns					
3720	0.898	17.3	157	761,907	249,854
Analysis Scenario (ii) without Special Movement Classes					
3720	0.898	19.2	157	794,784	255,775

Findings

The following can be observed from the SIDRA INTERSECTION results for the example:

- There are significant **differences in platoon characteristics** (percent arriving during green and platoon ratio) modelled per lane and per movement. As a result, there can be **significant differences in performance statistics** estimated on a per lane and per movement (lane group) basis.
- Although the performance estimates for different analysis scenarios look close generally, the **differences in individual lane values can be significant especially for the back of queue estimates** when:
 - the approach (midblock) distance between intersections is low and **lane blockage** effects are likely to come in, and
 - when sensitivities are higher at higher degrees of saturation.

Findings

- The use of **Special Movement Classes** improves the quality of estimation of signal coordination effects and this can have a significant impact on performance estimates, especially the queue length (and the corresponding probability of blockage).
- **Average delay values per movement can hide larger values of lane delay** when there is significant unequal lane use.

Conclusions

A lane-based analytical network model that derives second-by-second platoon patterns as a function of signal offsets for signalised intersections is discussed. The **importance of modelling individual lane departure and arrival patterns**, and consideration of implied **midblock lane changes** have been emphasised.

This method coupled with a lane-based model allowing for the **backward spread of congestion** and upstream **capacity constraint** is expected to produce better results in **assessing signal coordination quality** and optimising signal offsets.

There are significant differences in **platoon characteristics modelled per lane and per movement**, and with and without the use of the **Special Movement Class** method. As a result, there can be significant differences in performance statistics.

Conclusions

Performance statistics estimated on a **per lane** and **per movement (lane group / link)** basis may lead to different conclusions. Lane performance values are better indicators of intersection operating conditions.

Detailed analyses as described in this presentation are justified for **important projects involving design of networks of closely-spaced intersections** as in this example.

Real-life surveys of lane use at closely-spaced intersections and analyses using **micro-simulation** to compare results with those from analytical models are recommended.



END OF PRESENTATION

Thank you!

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