Modelling signal platoon patterns by approach lane use and movement class

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The Presenter

Dr Rahmi Akçelik is a leading scientist and software developer with over 300 technical publications in his area of expertise. He is the author of the SIDRA INTERSECTION and SIDRA TRIP software.

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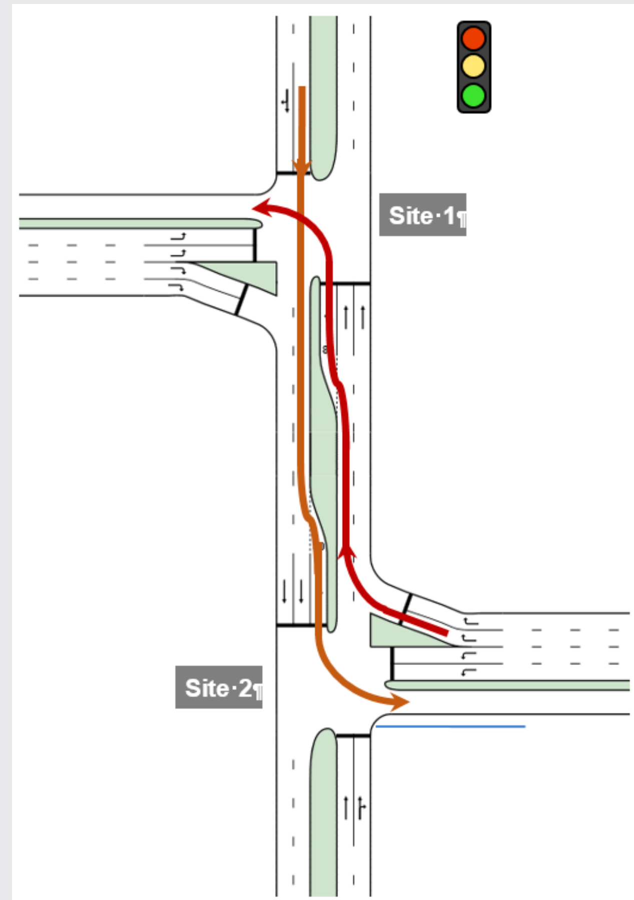
The Paper

Modelling signal platoon patterns by approach lane use and movement class

The modelling of signal platoon patterns is further enhanced by using **SPECIAL MOVEMENT CLASSES**. These are movements which become **turning movements** at downstream internal approaches. These movements can be assigned to **separate lanes** and **separate signal phases**, and their second-by-second platoon patterns can be **tracked through the network separately**.

This improves the quality of **signal platoon modelling** and is expected to produce better results in **assessing signal coordination quality** and optimising signal offsets.



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The Presentation

Lane-based network model

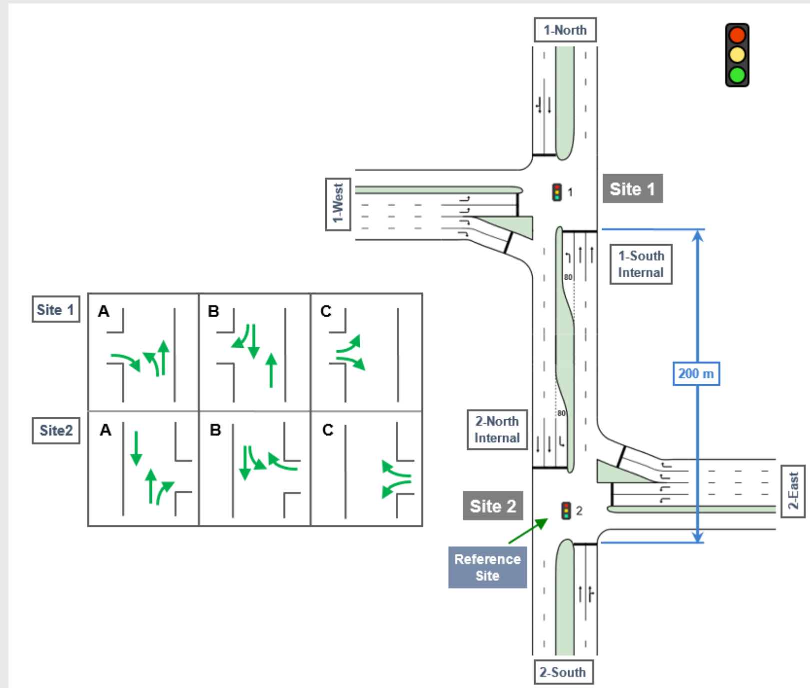
Movement Classes

Signal platoon model

Example : Staggered T intersection

Findings

Conclusions



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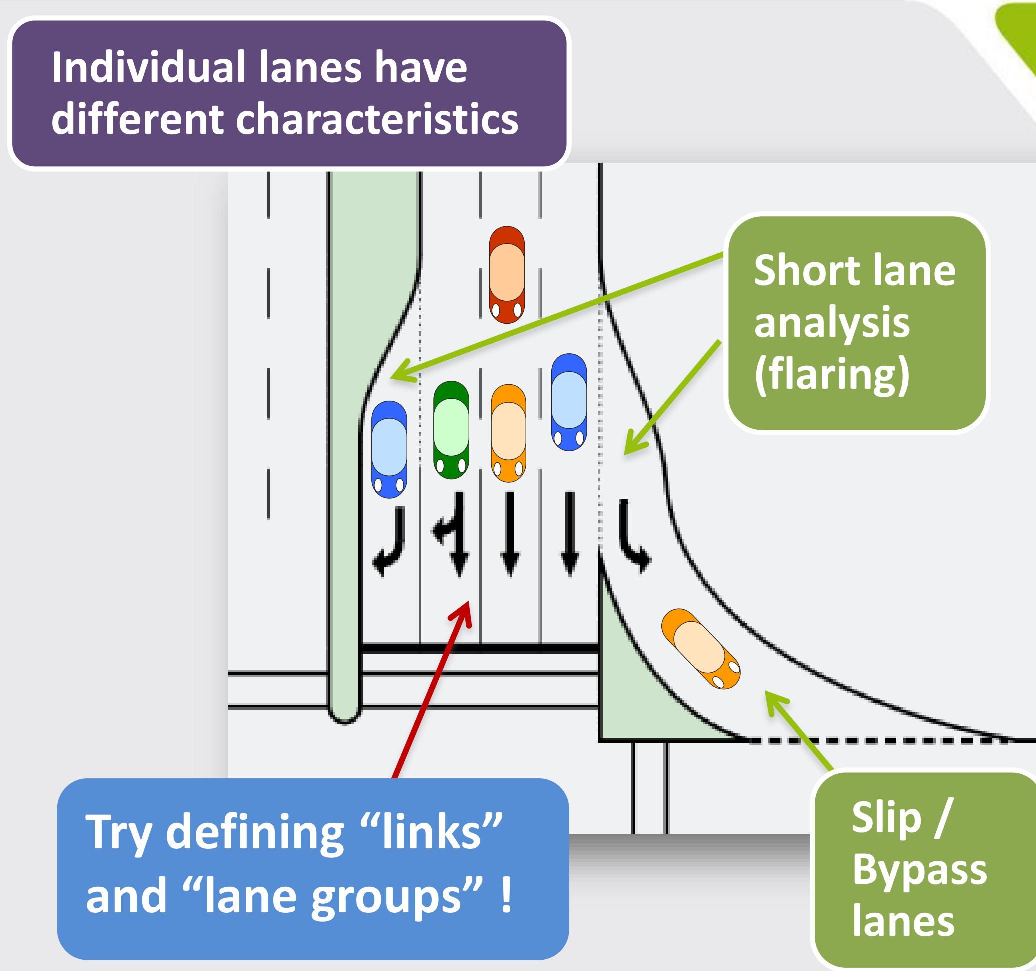
Lane-based model for Intersections and Networks

LANE-BASED MODEL

More realistic and reliable analysis compared with traditional approach-based and lane group (link) - based methods.

- 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).



Lane-based model for NETWORKS

Lane-based model is particularly important in evaluating

- closely-spaced intersections
- high demand flows
- cases 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.

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Basic aspects of the Lane Based Network Model

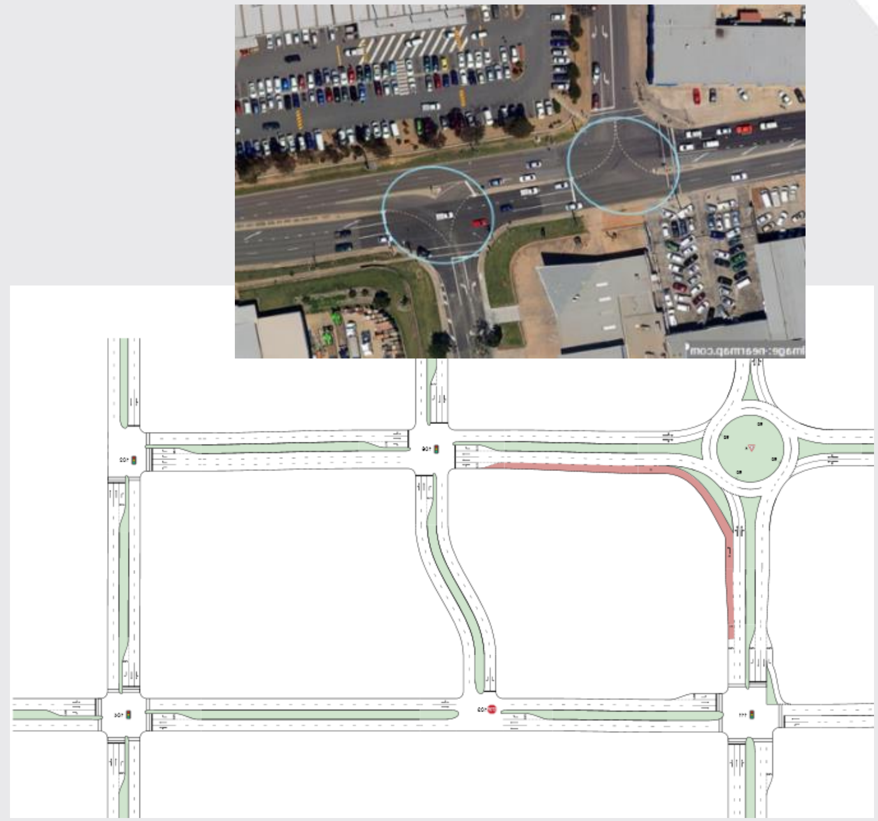
Developed for the **SIDRA INTERSECTION** software

Lane blockage and **capacity constraint** using an **iterative method**

Importance of **back of queue** model and **lane-based probability of blockage**

Use of **Special Movement Classes** for closely-spaced intersections

Signal platoon model



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

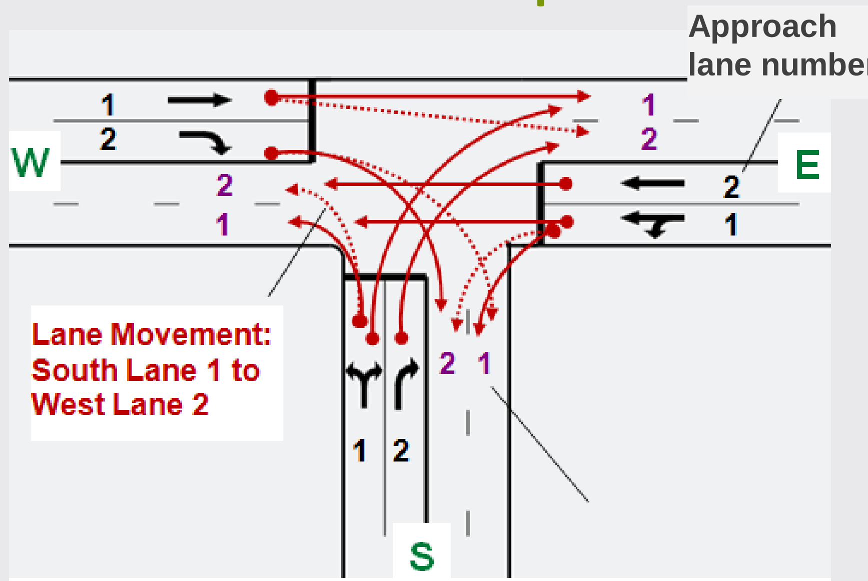
Departure patterns at upstream lanes

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.

Lane Movement Flow Proportions



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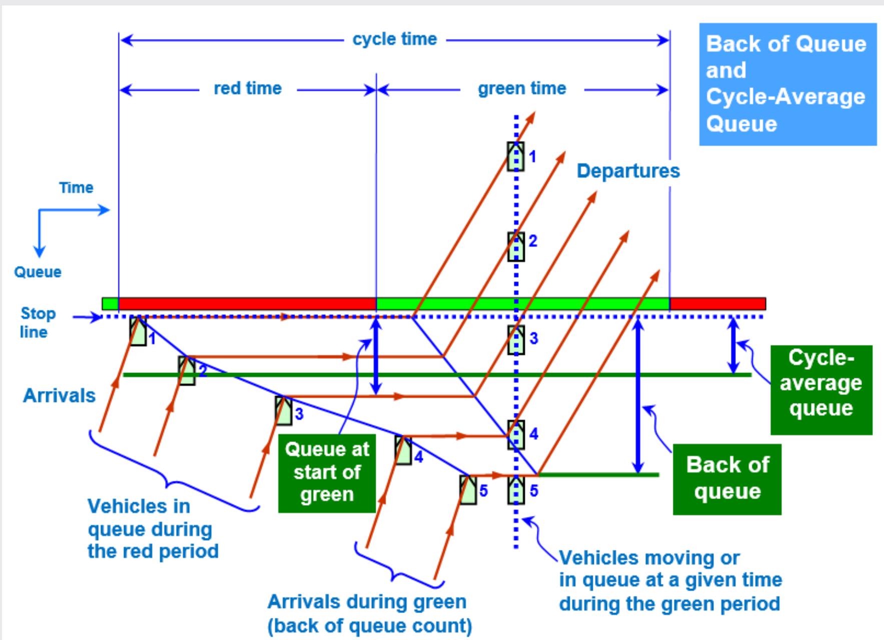
Importance of Back of Queue model

Back of Queue Percentile and **Probability of Blockage** values are based on the **variability of back of queue** values in individual lanes



Back of Queue is important for modelling of **short lane overflow** and **queue spillback in networks**

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 modelling of **Bus Priority Lanes**, **Bicycle Lanes**, and so on …

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Special Movement Classes

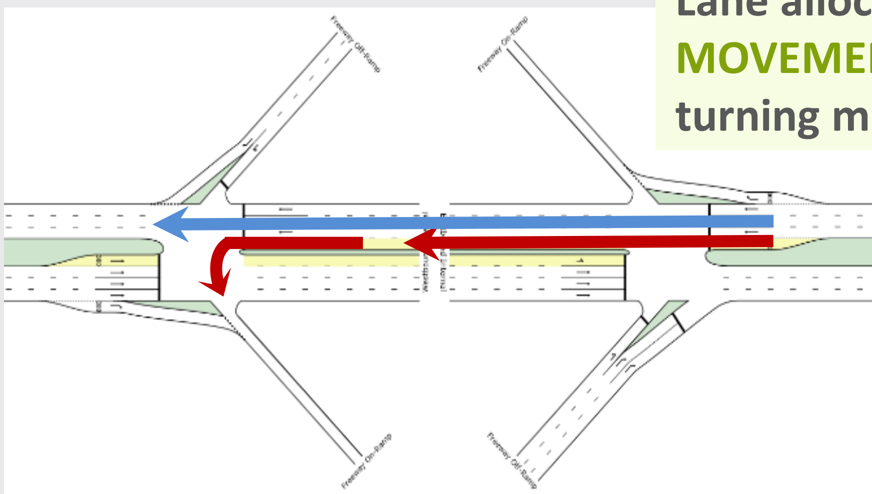
The modelling of signal platoon patterns is enhanced by using Special Movement Classes. Examples:

- through movements at external approaches that become turning movements at downstream internal approaches
- dogleg movements at staggered T intersections.

These movements can be assigned to separate lanes and separate signal phases, and their second-by-second platoon patterns can be tracked through the network separately.

Special Movement Classes:
Freeway Diamond Interchange example

Lane allocation by **SPECIAL MOVEMENT CLASSES** for turning movements



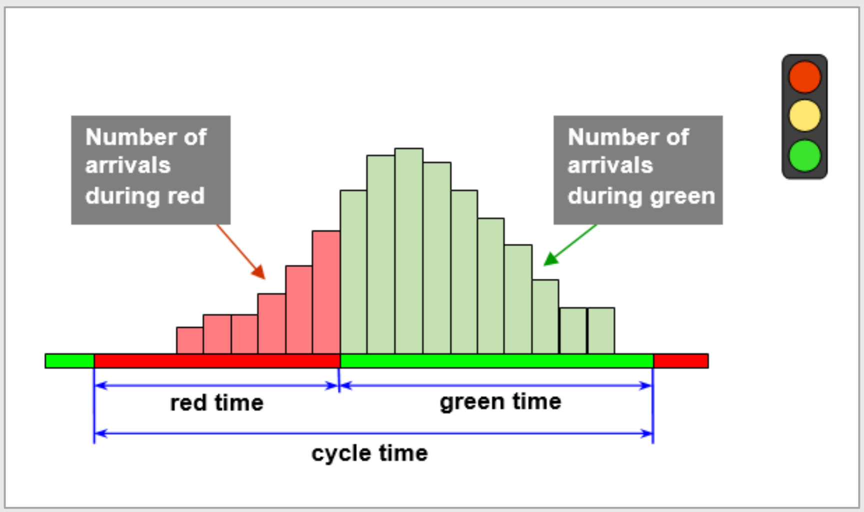
Signal Platoon Model

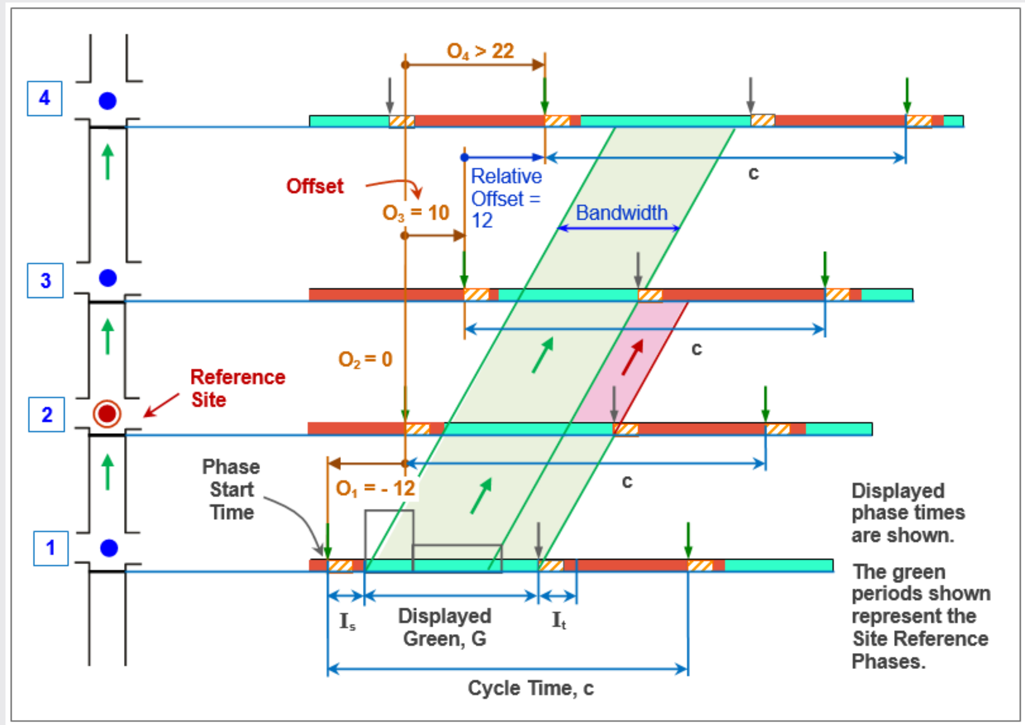
Using signal offsets for signal coordination, lane-based (not link-based) second-by-second platoon patterns are modelled to estimate

Percent Arriving During Green

Platoon Ratio

Arrival Types





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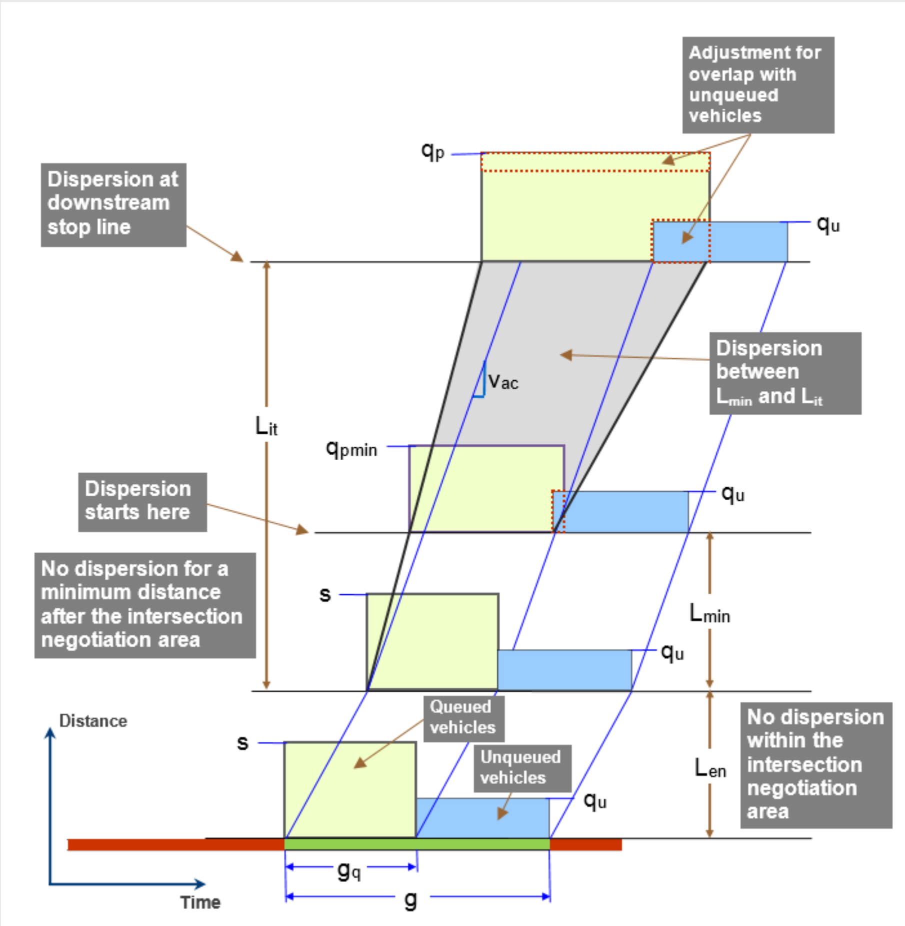
Platoon Dispersion Model



No platoon dispersion in short distances

Uniform dispersion model

	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.

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Lane-based modelling of signal platoons

The lane-based modelling of platoon arrival patterns at downstream approach lanes takes into account

- 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 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.

Lane-based modelling of signal platoons

The new analytical lane-based method for determining platoon patterns at closely-spaced signalised intersections is expected to improve assessment of signal coordination quality and optimisation of signal offsets.

This differs from the traditional network models that use LINKS or LANE GROUPS.

In traditional network models:

- individual lane conditions are aggregated, and as a result
- there is not sufficient information about queue lengths, lane blockage probabilities, backward spread of queues, and so on since these need lane level of detail.

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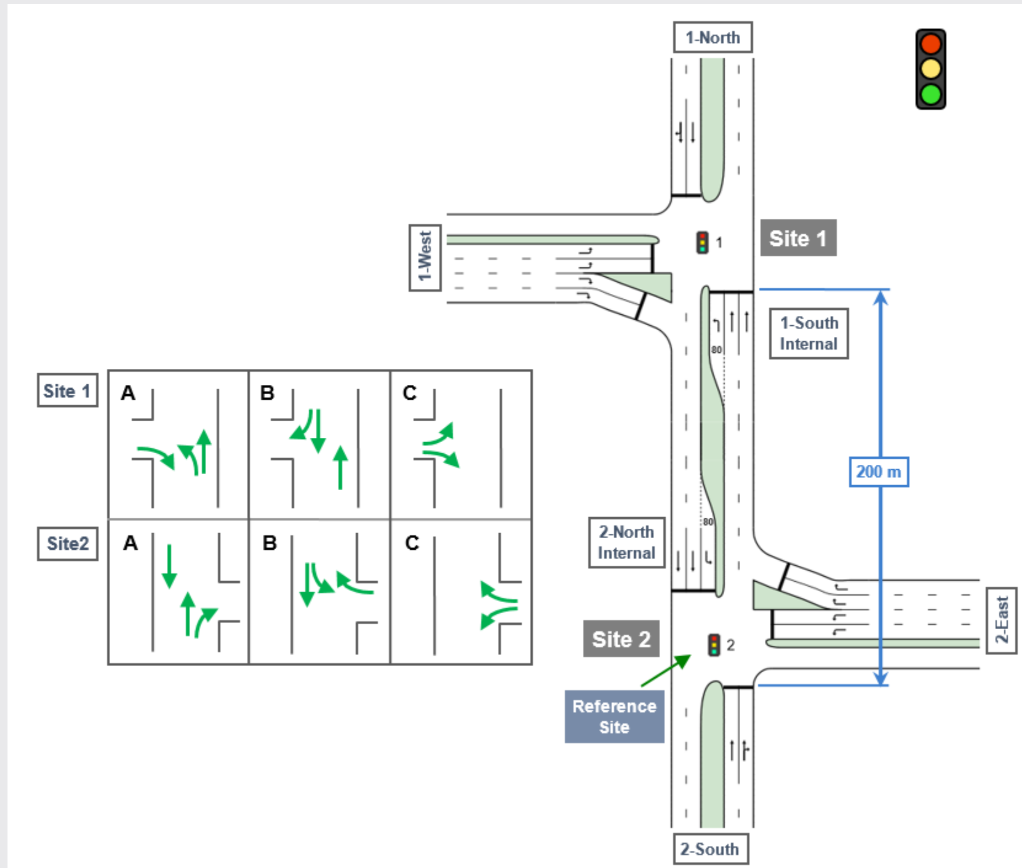
Example : Staggered T intersections

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 200 m distance between them.

Detailed description is given in the paper.



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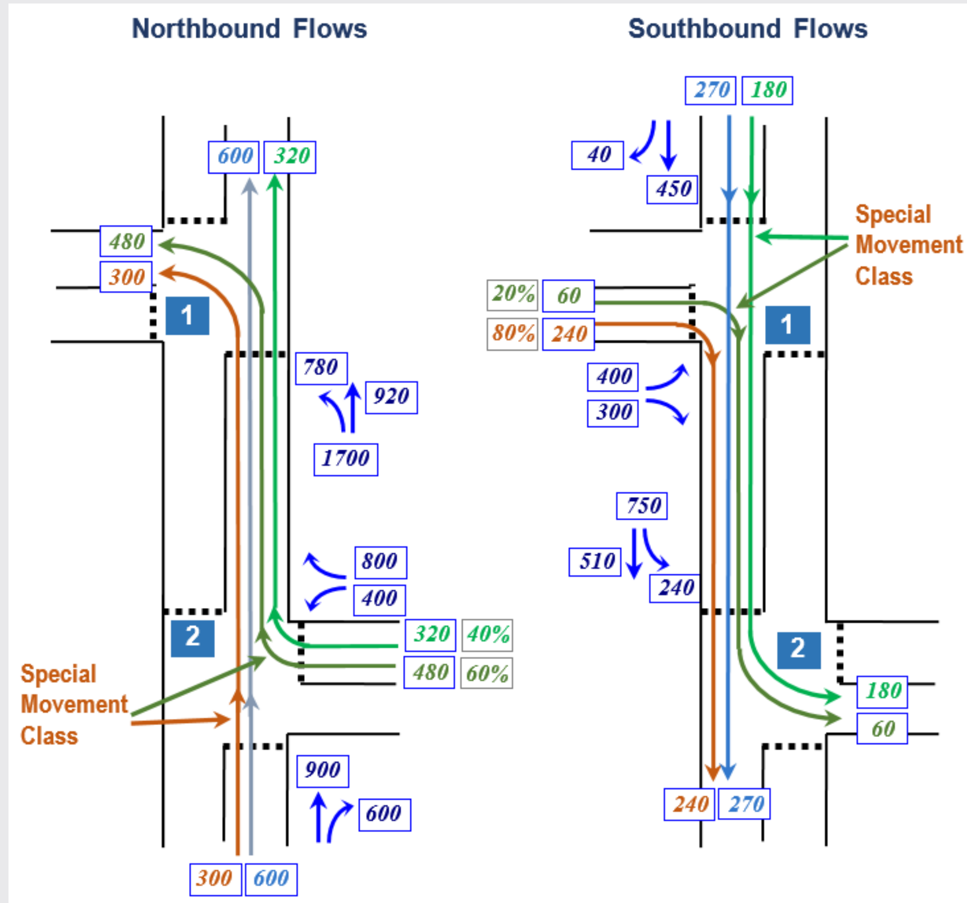
Site and Network Origin-Destination Flows

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 are also used for analysing differences between analysis scenarios **with and without knowledge of Network OD flows**.



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Analysis Scenarios

Two analysis scenarios are considered to investigate the differences between the network model results including signal platooning and the resulting performance estimates with and without the use of Special Movement Classes.

Many other analysis scenarios are possible considering different lane use patterns and Lane Movement Flow Proportions.

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

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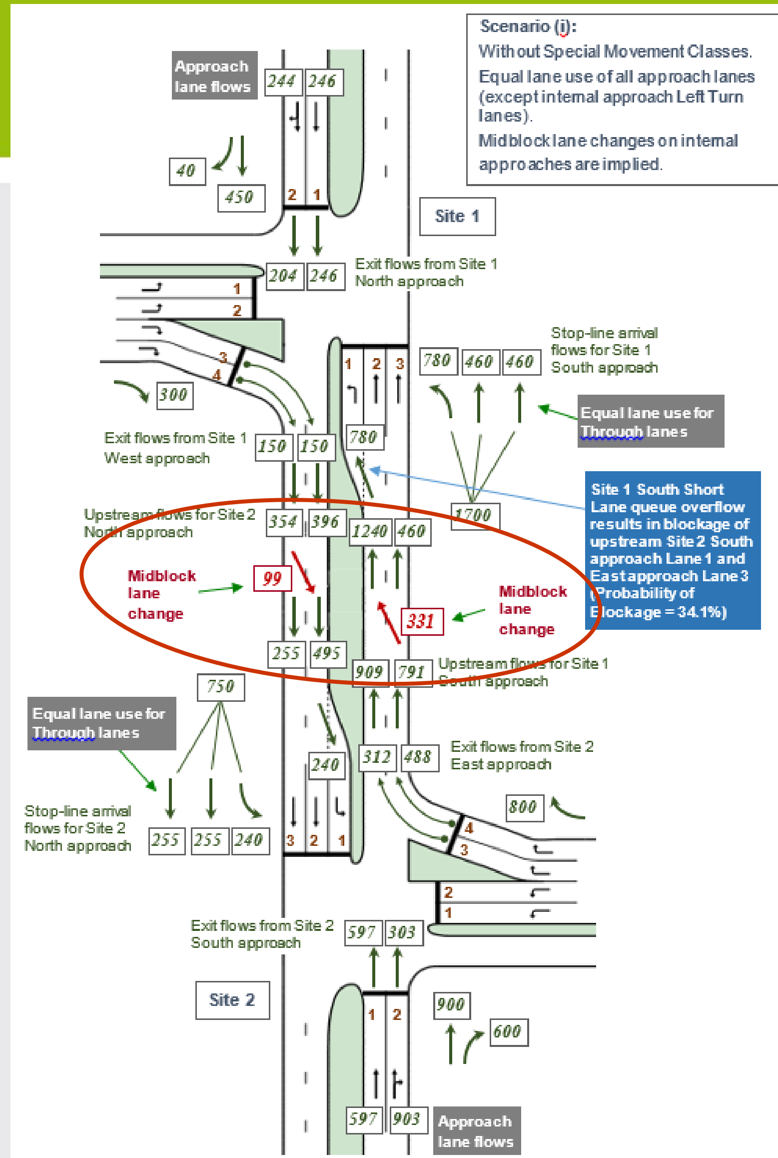
Analysis Scenario (i)

Only the Site OD flows (intersection turning volumes) are known at each intersection, and the **Network OD flows are not known**.

Default Lane Movement Flow Proportions are used: 100% flow to the most direct exit lane.

Equal lane use (equal degrees of saturation) applies to lane groups. This results in **implied midblock lane changes**.



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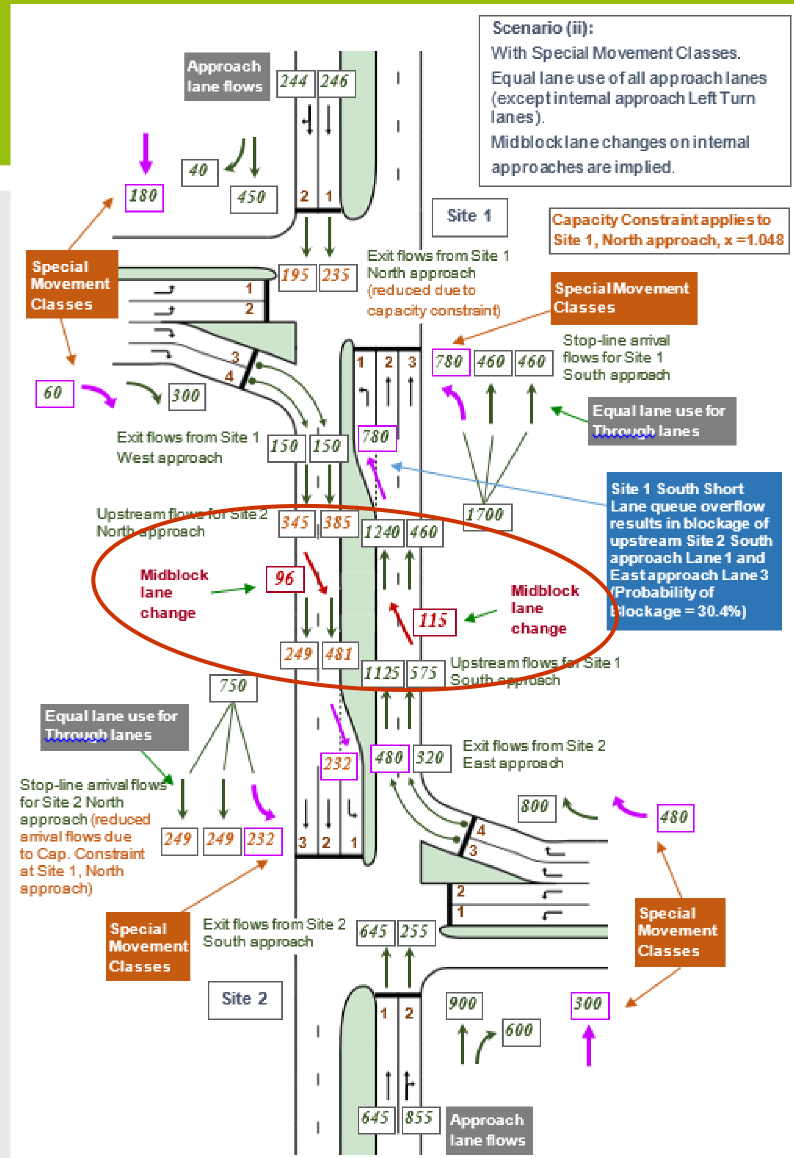
Analysis Scenario (ii)

Network OD flows are known in addition to the Site OD flows.

Special Movement Classes are assigned to upstream and downstream lanes according to destinations at the downstream intersection

Equal lane use (equal degrees of saturation) applies to lane groups. except for Site 2, East approach Lanes 3 and 4 (Right Turn) with Special MCs in Lane 3 .

This results in **implied midblock lane changes**.



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Lane results for Site 1 South approach lanes and Site 2 East approach lanes

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) WITHOUT Special Movement Classes: Site 1 South approach							
Lane 1	780	831	0.939	**57.1%**	**1.007**	47.1	281
Lane 2	460	1472	0.313	**78.5%**	**1.024**	3.1	40
Lane 3	460	1472	0.313	**66.0%**	**0.869**	4.5	59
Analysis Scenario (i) WITHOUT Special Movement Classes: Site 2 East approach							
Lane 3	312	390	0.801	33.3%	1.000	42.1	101
Lane 4	488	609	0.801	33.3%	1.000	39.0	149
Analysis Scenario (ii) WITH Special Movement Classes: Site 1 South approach							
Lane 1	780	867	0.900	**38.5%**	**0.641**	36.4	255
Lane 2	460	1493	0.308	**97.1%**	**1.248**	0.8	6
Lane 3	460	1493	0.308	**88.2%**	**1.134**	3.2	23
Analysis Scenario (i) WITH Special Movement Classes: Site 2 East approach							
Lane 3	**480**	**503**	**0.954**	37.8%	1.000	68.7	215
Lane 4	**320** *	**691**	**0.463** *	37.8%	1.000	28.4	75

* **Lane underutilisation**

Significant difference in platoon patterns

Results for internal Left and Through (platooned) movements on Site 1 South internal approach (Northbound)

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) WITHOUT Special Movement Classes: Site 1 South approach						
Left	780	0.939	**57.1%**	**1.007**	47.1	281
Through	920	0.313	**72.6%**	**0.947**	3.8	59
Analysis Scenario (ii) WITH Special Movement Classes: Site 1 South approach						
Left	780	0.900	**38.5%**	**0.641**	36.0	255
Through	920	0.308	**92.7%**	**1.191**	1.2	23

Significant difference in platoon patterns

Total Delay, Cost, Fuel and Emission Results for the Network

Significant difference in estimates of network performance

Total Demand Flow (veh/h)	Degree of Saturation (v / c)	Total Delay veh-h/year	Total Operating Cost ($/h)	Total Fuel Consumption (L/year)	Total CO2 Emission (kg/year)	Total HC Emission (kg/year)	Total CO Emission (kg/year)
Analysis Scenario (i) - WITHOUT Special Movement Classes							
3,043,200	0.939	28,329	1,804,480	214,944	505,119	226	2,499
Analysis Scenario (ii) - WITH Special Movement Classes							
3,043,200	1.048	34,635	1,963,425	220,950	519,233	240	2,544
Difference							
-	12%	22%	9%	3%	3%	6%	2%

Findings -1

The following can be observed from the results given for the example:

- There are significant differences in signal platoon characteristics (per lane and per movement) estimated with and without the use of Special Movement Classes.
- Use of Special Movement Classes helps with automatic identification of external approach lane underutilisation.
- Signal timings get affected by unequal lane use, and these in turn affect platoon characteristics, delay and queue length results.
- The midblock lane change flow rate for Northbound movements is significantly smaller with the use of Special Movement Classes. This provides better estimates of lane use on external approaches according to downstream destinations.

Findings - 2

- The example shows lane blockage of upstream Site lanes because of downstream short lane overflow and capacity constraint due to oversaturated upstream lanes.
- Southbound platoon movements are affected by capacity constraint due to oversaturated lanes on the North approach of Site 1 under Analysis Scenario (ii). This results in reduced arrival flow rates for movements on the North approach of Site 2. This is not observed under Analysis Scenario (i).
- Under both scenarios, short lane queue overflows from Lane 1 of Site 1 South approach. This results in the adjacent lane queue blocking lanes at Site 2 (Lane 1 of the South approach and Lane 3 of the East approach), thus causing capacity reductions on these lanes. The amount of blockage is different under Analysis Scenarios (i) and (ii).

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Findings - 3

- The differences in individual lane performance values with and without the use of Movement Classes can be significant especially for the BACK OF QUEUE estimates when
  - the approach (midblock) distance between intersections is small, and therefore lane blockage effects are likely to come in, and
  - when sensitivities are higher at high degrees of saturation.
- AVERAGE DELAY values per movement can hide larger values of delay in individual lanes used by the movement when there is significant unequal lane use.
- The differences in site and network performance estimates can be significant.

Conclusions -1

The lane-based analytical network model developed for the SIDRA INTERSECTION software including a lane-based platoon model for coordinated signals is discussed.

The following important aspects of the model have been emphasised:

- modelling of unequal lane use on external approaches of closely-spaced intersections
- modelling of individual lane departure and arrival patterns with consideration of implied midblock lane changes.

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 compared with traditional models based on the use of lane groups or links (movements).

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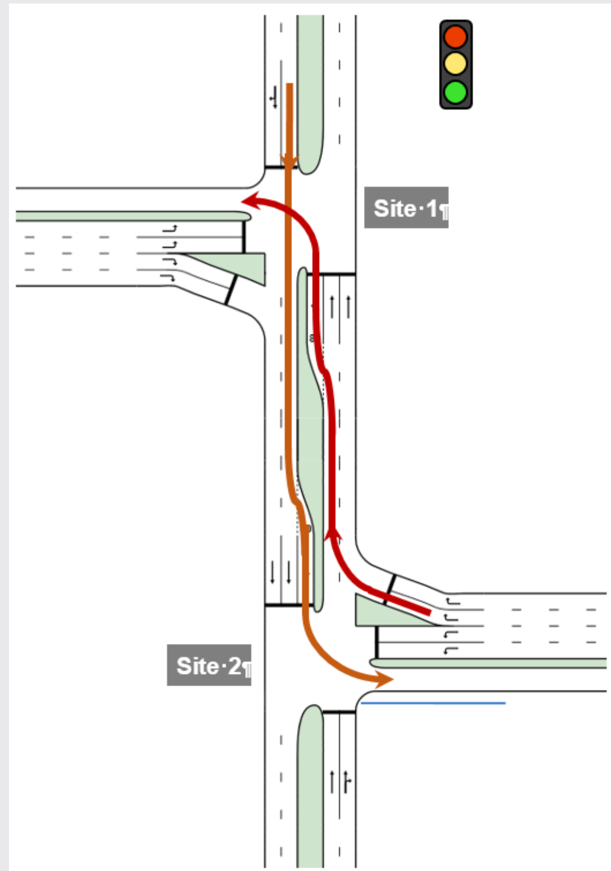
Conclusions - 2

The use of Special Movement Classes to represent external approach movements that continue as turning movements on internal approaches helps with better estimation of the unequal lane use often observed at external approach lanes of closely-spaced intersections due to the network origin - destination effects.

These are important in detailed analysis required for important projects involving design of small-sized networks as in the example presented in the paper.



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Conclusions -3

Further analyses of different lane use scenarios are recommended for their effects on signal platoon patterns and resulting performance estimates.

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.

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END OF PRESENTATION

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