A New Lane-Based Model for Platoon Patterns at Closely-Spaced Signalised Intersections

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A New Lane-Based Model for Platoon Patterns at Closely-Spaced Signalised Intersections

The presentation:

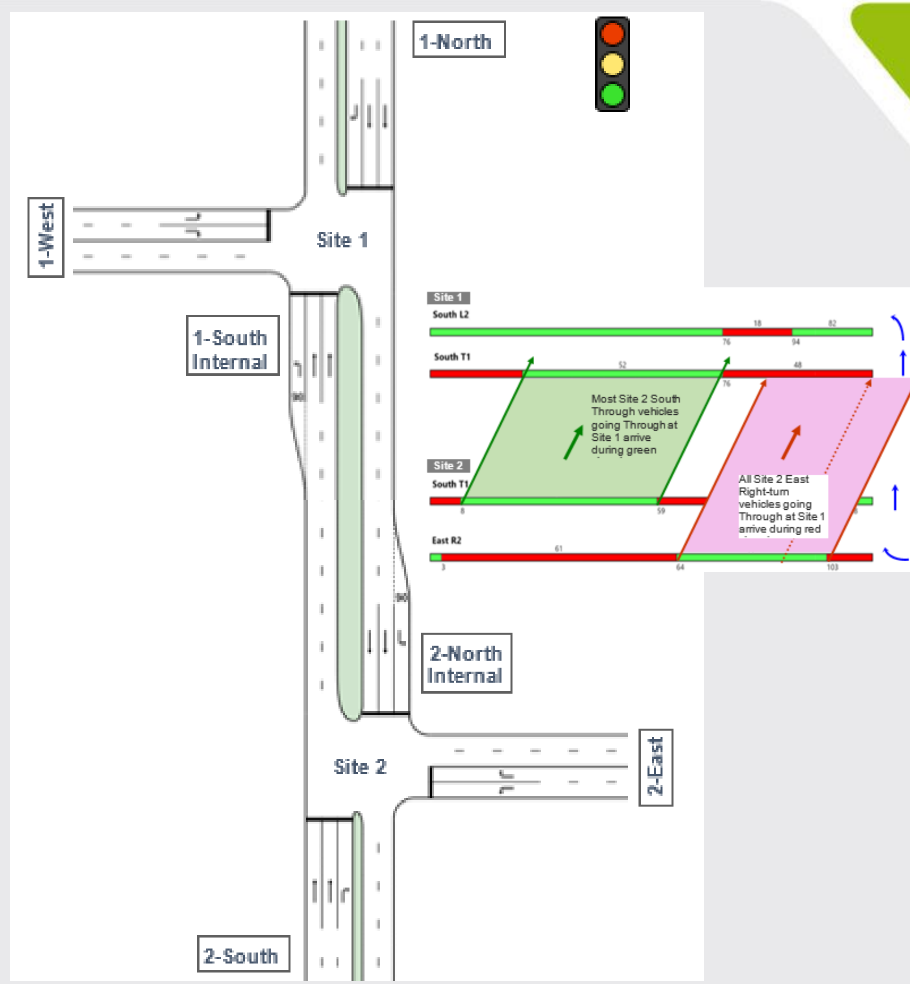
Basic features of the lane-based network model

- Lane-based model
- Departure patterns
- Arrival patterns
- Signal platoon model

Example : Staggered T intersection

Findings

Conclusions



Basic features of the lane-based network model

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“:

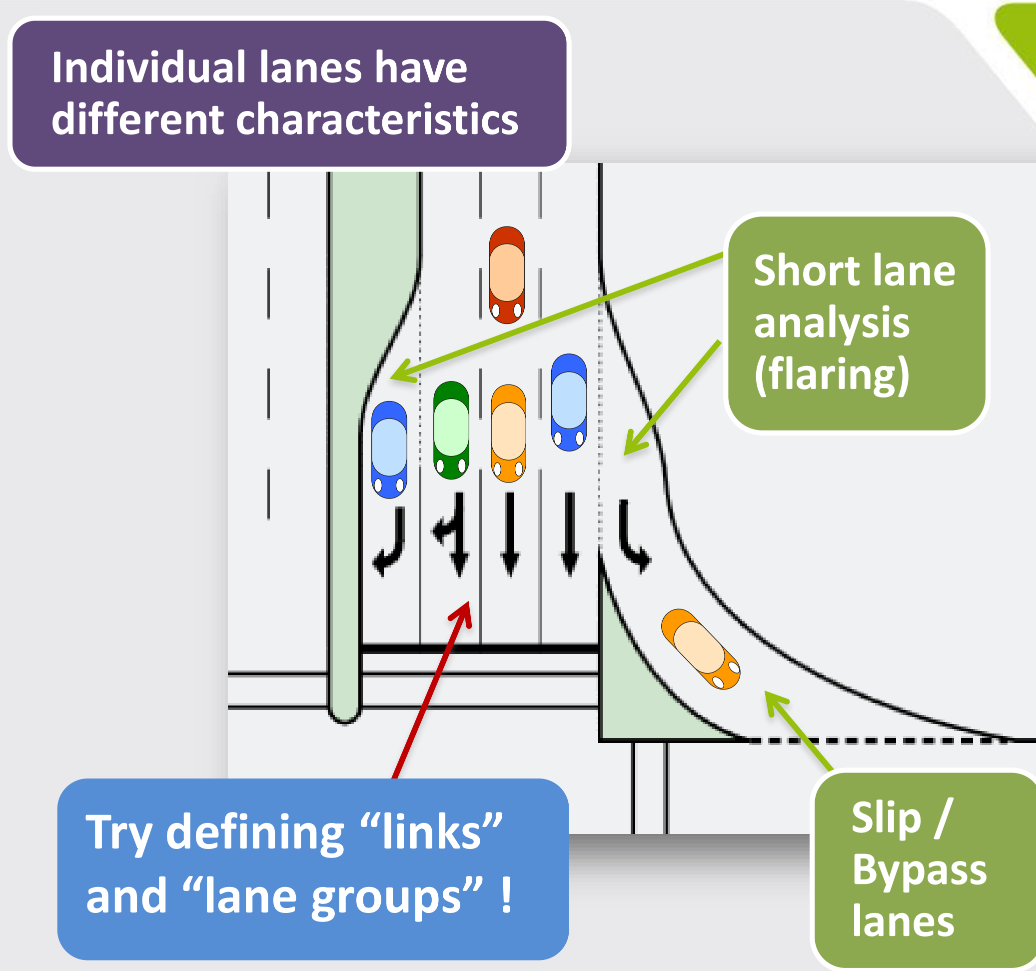
- individual lane conditions are aggregated
- insufficient information about queue lengths, lane blockage probabilities, backward spread of queues, and so on as these need lane level of detail.

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 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).



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

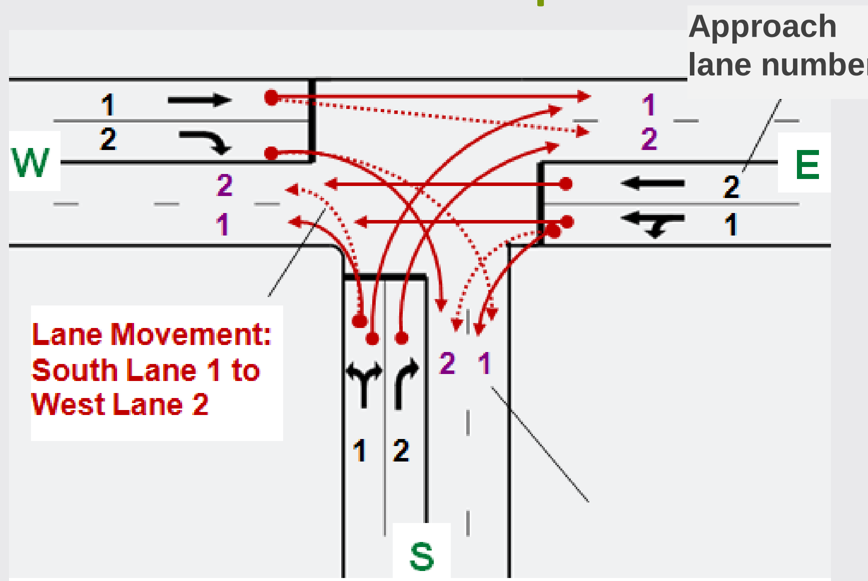
- **capacity reduction due to lane blockage by downstream queues**
- **reduced arrival flows due to capacity constraint at oversaturated upstream lanes**
- **lane movement flow proportions at the upstream intersection.**

Departure patterns at upstream lanes

Backward spread of congestion (reduced upstream capacity)

Capacity constraint (reduced downstream arrival flows)

Lane Movement Flow Proportions



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

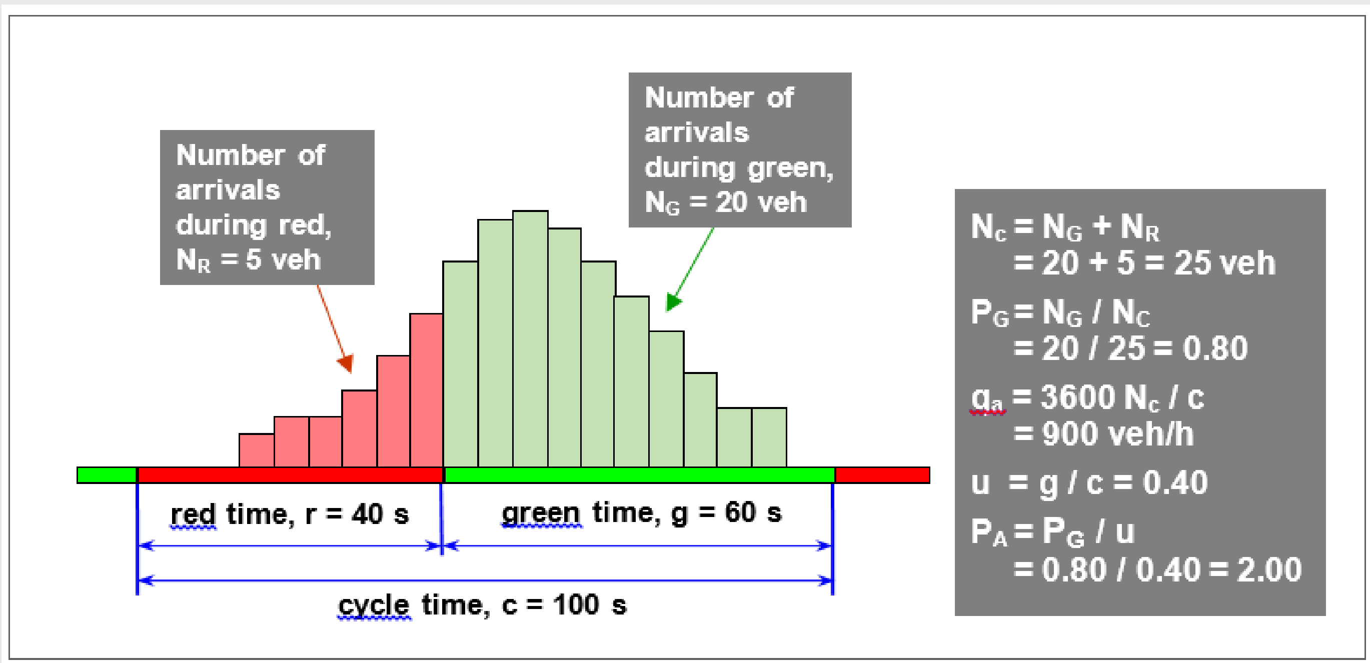
The modelling of platoon arrival patterns at downstream approach lanes takes into account

- 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.

The model is expected to improve assessment of signal coordination quality and optimisation of signal offsets.

Signal platoon model

The second-by-second arrival patterns determined by the program are used to calculate the following parameters for each approach lane for use in performance calculations: Percent Arriving During Green, P_G and Platoon Ratio, P_A.



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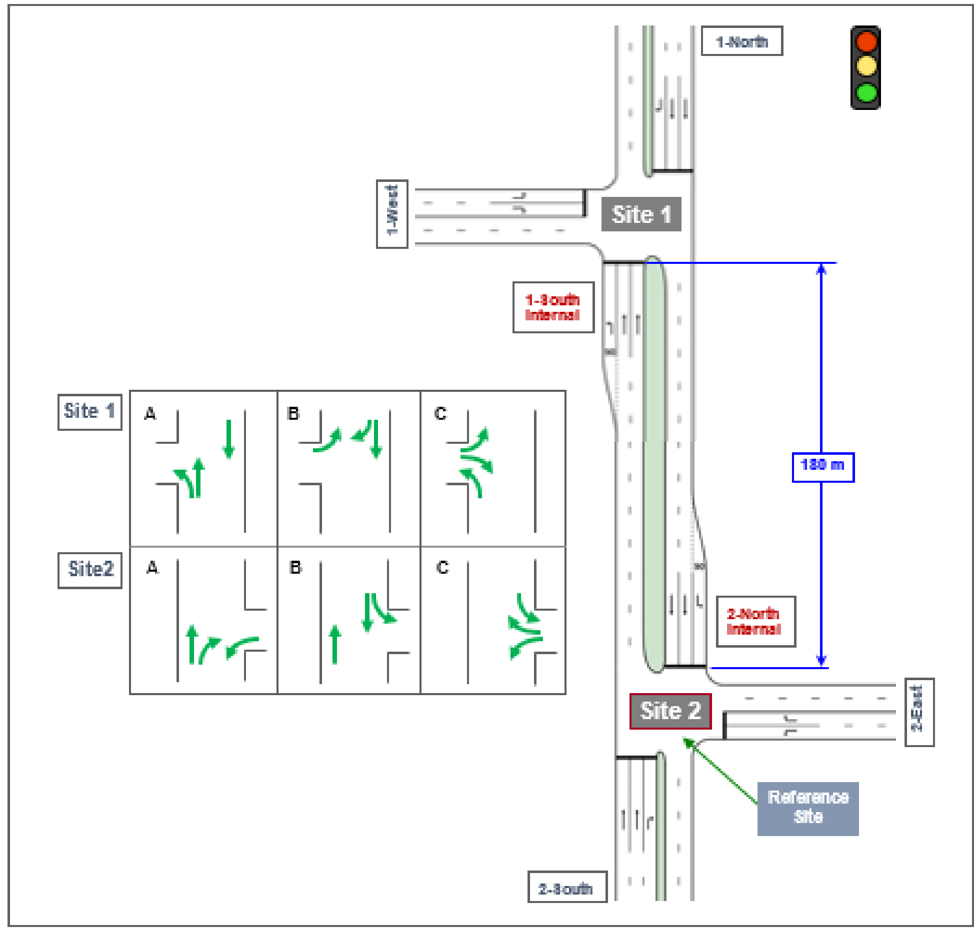
Example : Staggered T intersections

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 180 m distance between them.

Detailed description in the paper.



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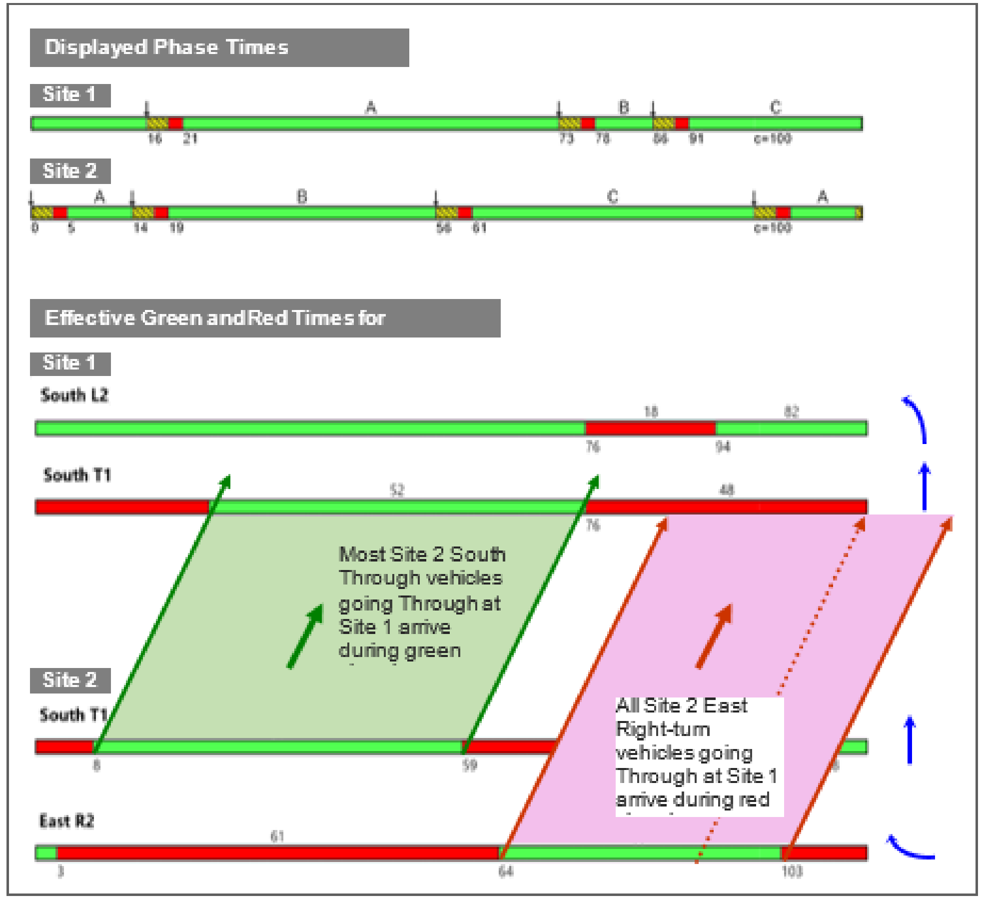
Example : Signal coordination

Network Cycle Time = 100 s. **Phase Times** calculated applying "**green split priority**" to internal approach movements.

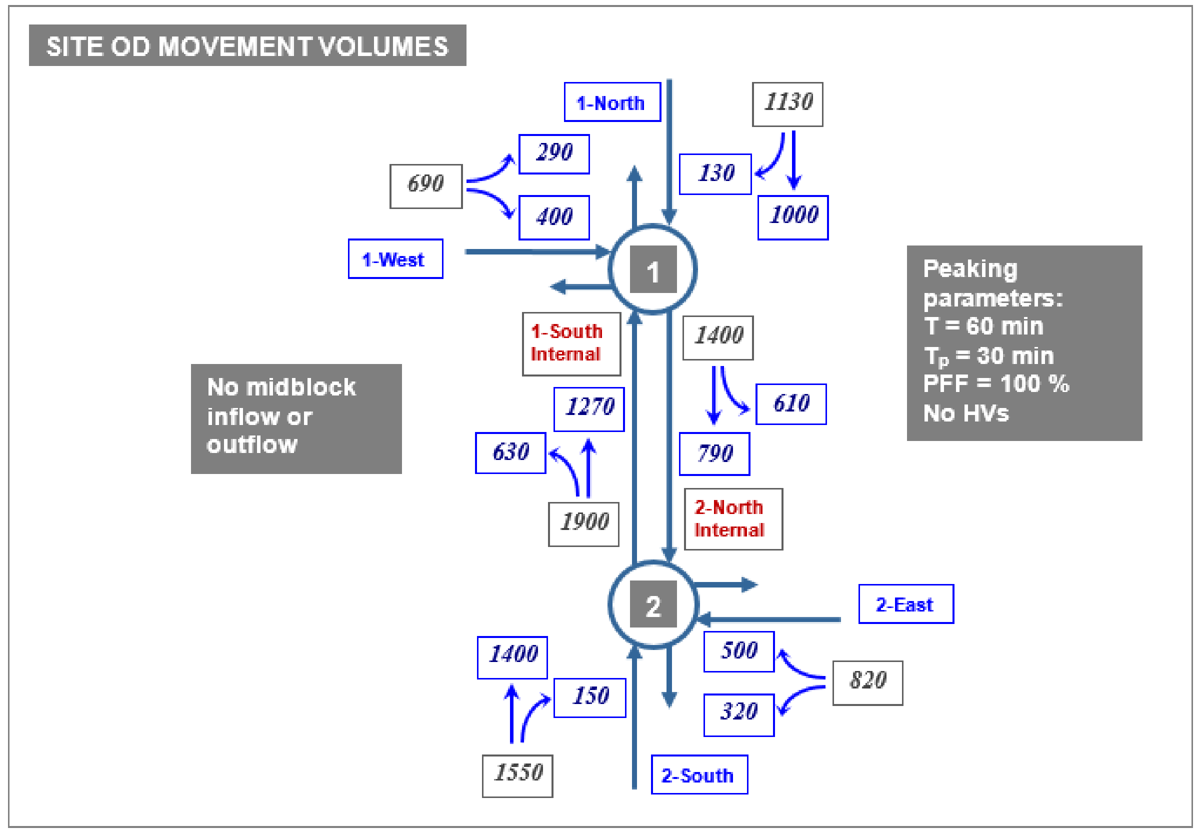
For signal coordination, **Site 2 is the Reference Site** (Offset = 0), and Phase A is the Reference Phase for both Sites. **Travel Time Offset = 16 s** specified for Site 1.



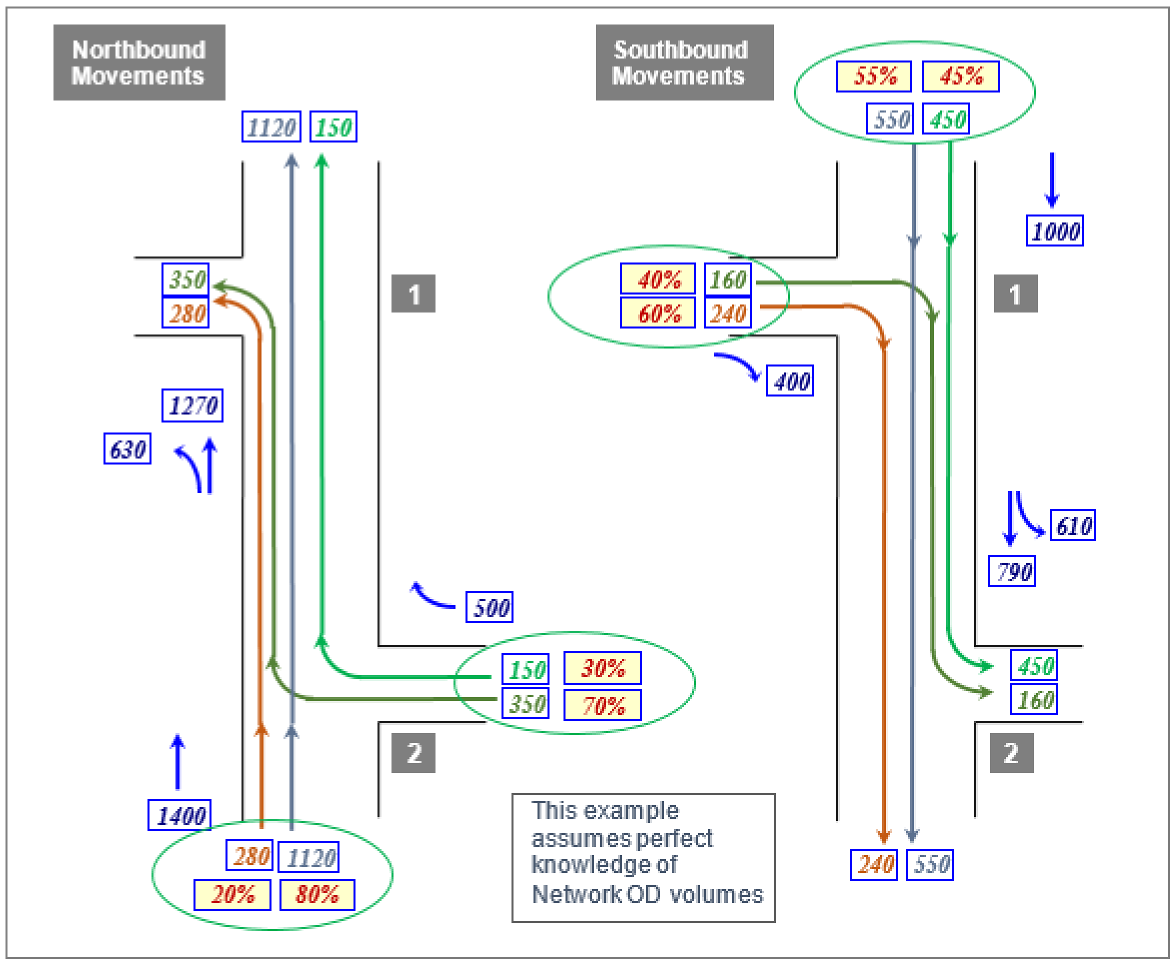
Site OD flows and Network OD flows

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



Analysis Scenarios

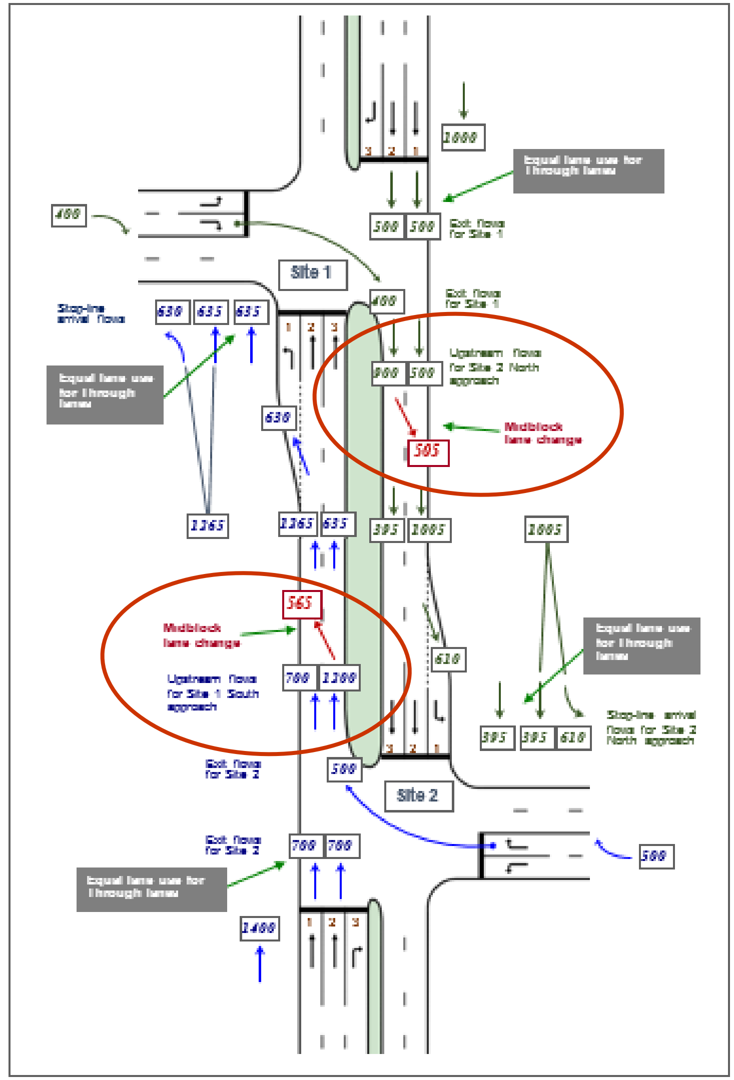
Three analysis scenarios are considered to investigate the differences between signal platooning and the resulting performance estimates according to the assumptions about approach lane use and exit lanes chosen in departing from an intersection.

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

Many other analysis scenarios are possible considering different lane use patterns and Lane Movement Flow Proportions. The presentation was limited to three analysis scenarios.

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** used: 100% flow to the most direct exit lane.
- **Equal lane use** for all Through approach lanes. This results in **implied midblock lane changes**.



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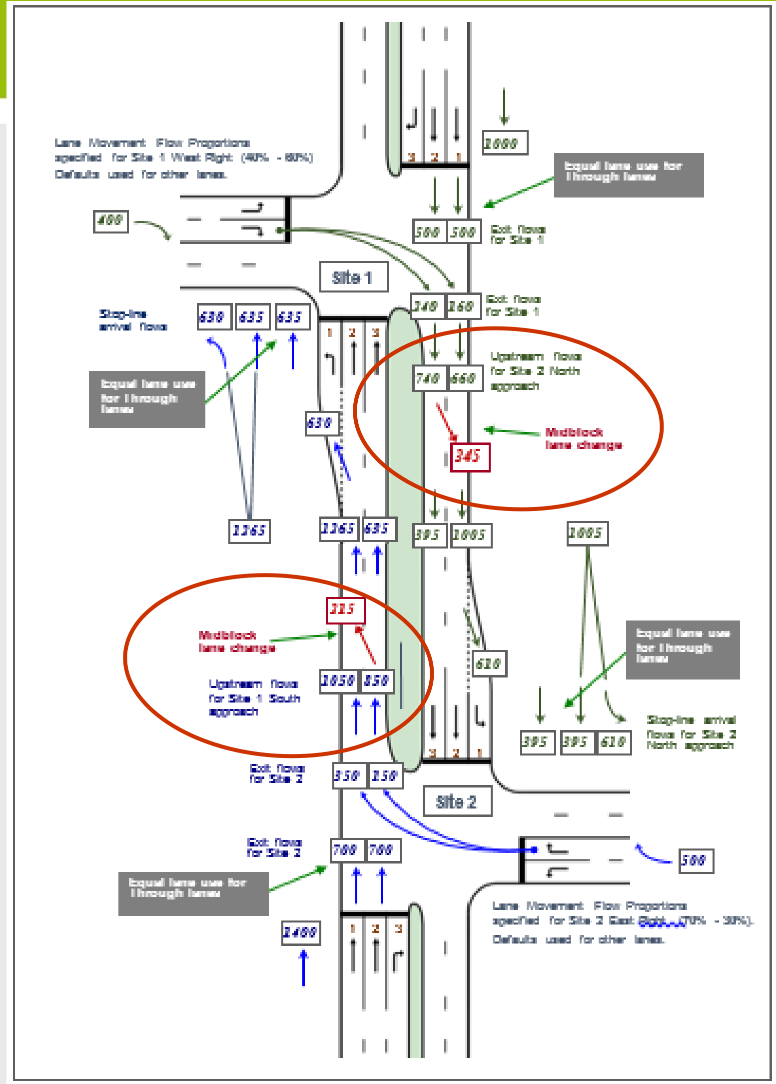
Analysis Scenario (ii)

- Network OD flows are known in addition to the Site OD flows.
- 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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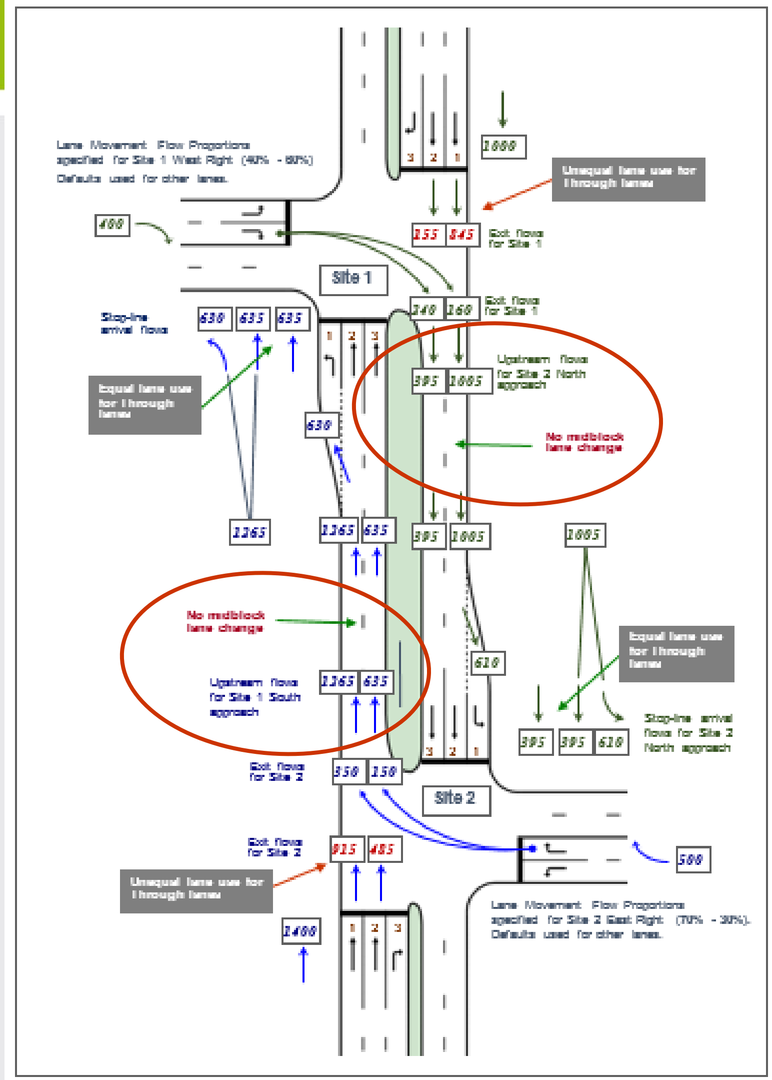
Analysis Scenario (iii)

- **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
- There are **no midblock lane changes**. This assumes that **drivers select their lanes correctly at the first intersection** according to destinations at the next intersection. For this purpose, **unequal lane use** is assumed for Through movements at the upstream external approaches.



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Analysis results for the example

Detailed tables are presented in the paper for:

- **Comparisons of results for Scenarios (i) to (iii) for Through movement lanes on external and internal approaches.**
- **Comparisons of results for Scenarios (i) to (iii) for internal Left and Through (platooned) movements.**

Results for Analysis Scenarios (i) and (iii) for internal approach lanes and movements with platooned arrivals are given in the next two slides.

Lane results for internal approaches

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)							
SITE 1 - South Internal (NB)							
South Lane 2	635	988	0.643	80.3%	1.544	9.8	88
Lane 3	635	988	0.643	58.3%	1.122	20.7	144
SITE 2 - North Internal (SB)							
North Lane 2	395	703	0.562	50.9%	1.375	26.4	93
Lane 3	395	703	0.562	51.8%	1.399	26.0	92
Analysis Scenario (iii)							
SITE 1 - South Internal (NB)							
South Lane 2	635	988	0.643	68.0%	1.308	16.4	122
Lane 3	635	988	0.643	69.5%	1.337	15.7	119
SITE 2 - North Internal (SB)							
North Lane 2	395	817	0.483	53.4%	1.241	22.9	84
Lane 3	395	817	0.483	63.1%	1.467	18.6	71

Movement results for internal approaches

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)						
SITE 1 - South Internal (NB)						
Left	630	0.425	90.1%	1.099	5.7	34
Thru	1270	0.643	69.3%	1.333	15.3	144
SITE 2 - North Internal (SB)						
Left	610	0.416	85.1%	1.050	6.6	47
Thru	790	0.562	51.3%	1.387	26.2	93
Analysis Scenario (iii)						
SITE 1 - South Internal (NB)						
Left	630	0.425	88.7%	1.081	5.9	38
Thru	1270	0.643	68.7%	1.322	16.1	122
SITE 2 - North Internal (SB)						
Left	610	0.416	89.6%	1.106	5.8	34
Thru	790	0.483	58.2%	1.354	20.8	84

Intersection results for *Analysis Scenarios (i) to (iii)*

Arrival Flow (veh/h)	Degree of Saturation (v / c)	Average Delay (s)	95th %ile Back of Queue (m)	Total Operating Cost ($/h)	Total CO2 Emission (kg/h)
Analysis Scenario (i)					
SITE 1	Cycle Time = 100, Phase Times: 57, 13, 30				
3720	0.898	19.8	157	1646.6	531.0
SITE 2	Cycle Time = 100, Phase Times: 14, 42, 44				
3770	0.921	23.7	184	1860.8	542.3
Analysis Scenario (ii)					
SITE 1	Cycle Time = 100, Phase Times: 57, 13, 30				
3720	0.898	19.6	157	1617.3	526.1
SITE 2	Cycle Time = 100, Phase Times: 14, 42, 44				
3770	0.921	23.5	184	1854.0	541.3
Analysis Scenario (iii)					
SITE 1	Cycle Time = 100, Phase Times: 57, 13, 30				
3720	0.898	20.7	180	1684.4	539.0
SITE 2	Cycle Time = 100, Phase Times: 14, 48 38				
3770	0.921	24.0	279	1873.3	541.6

Findings

The following can be observed from the results given 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

- **Average delay values per movement can hide larger values of lane delay when there is significant unequal lane use.**
- **Scenario (iii) demonstrates the relevance of unequal lane use often observed at closely spaced intersections due to the network origin - destination effects.**
- **Signal timings get affected by unequal lane use, and these in turn affect platooning, delay and queue length results.**

Conclusions

A lane-based analytical network model that derives second-by-second platoon patterns 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. As a result, there can be significant differences in performance statistics estimated on a per lane and per movement (lane group / link) basis.

The example demonstrated the relevance of unequal lane use often observed at closely spaced intersections due to the network origin - destination effects.

Conclusions

The use of default lane flows (assuming equal lane use) and default Lane Movement Flow Proportions (exit to most direct lane) may be adequate for large-scale network analyses. However, more detailed analysis is justified for important projects involving design of small-sized networks as in this example.

After the writing of this paper, an enhancement was introduced to the analysis of closely-spaced intersections using SIDRA INTERSECTION. When the Network OD flows are known, external approach movements that continue as turning movements on internal approaches are specified as Special Movement Classes using the User Movement Class facility. 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.

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Conclusions

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.

END OF PRESENTATION

Thank you!

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