AITPM - SIDRA SOLUTIONS Webinar
17 February 2023

Network Analysis under Variable Demand Conditions - The SIDRA Method

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Presenters:
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Network Analysis under Variable Demand Conditions

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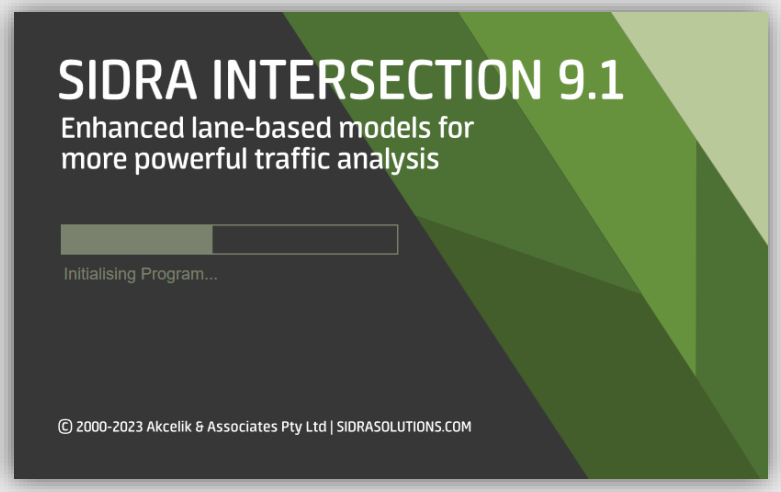


The SIDRA method for Variable Demand Analysis for intersections and networks is a new feature included in SIDRA INTERSECTION Version 9.1 released in November 2022.

SIDRA INTERSECTION
Current Status

About SIDRA

Signalised (and unsignalised) Intersection Design and Research Aid

First released in 1984

Continuous development in response to user feedback

SIDRA INTERSECTION 9.1

Micro-analytical software for modelling Intersections and Networks.

Current Version: 9.1
(24th major SIDRA version since its first release)

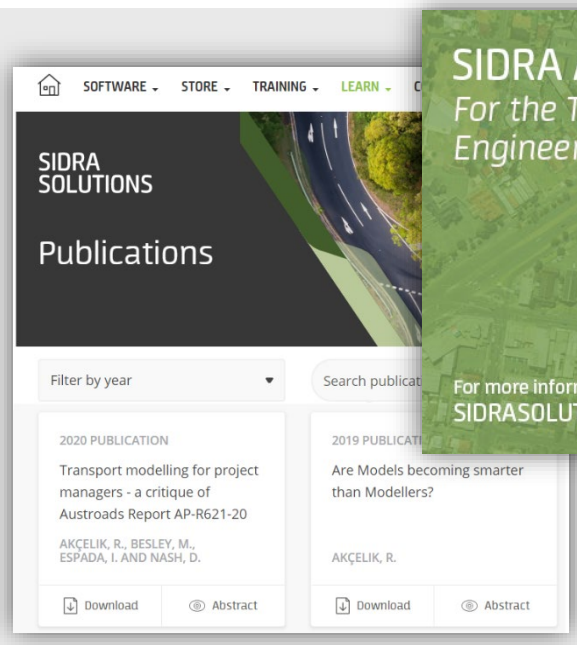
Current development:

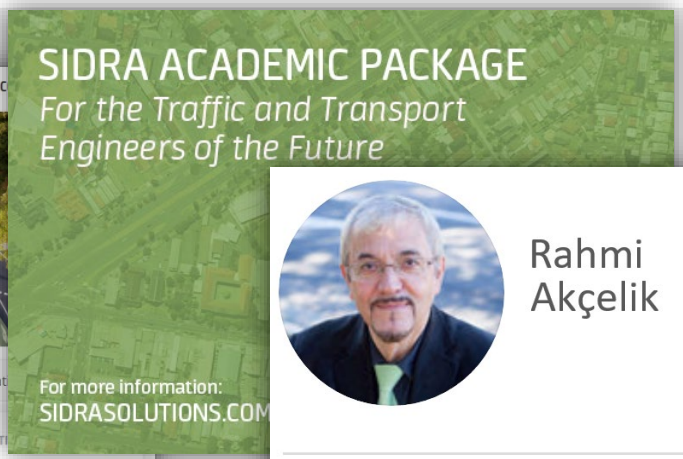
- SIDRA INTERSECTION Version 10
- SIDRA TRIP Version 2

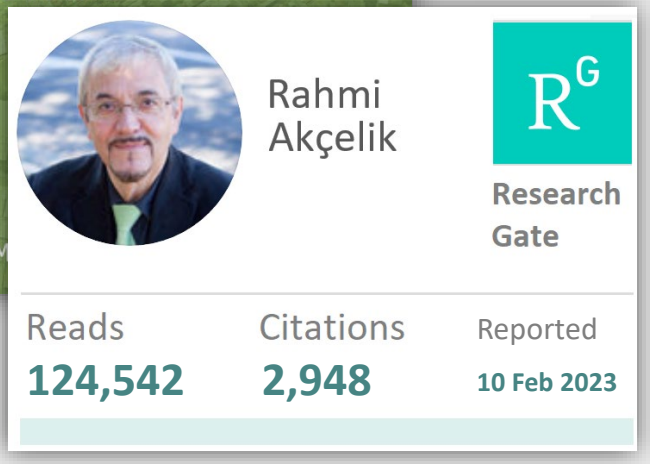
STRONG RESEARCH BASE of SIDRA

Analytical traffic modeling:
Empirical and theoretical methods combined

20 years at Australian Road Research Board
20+ years at Akcelik & Associates (since 1999)







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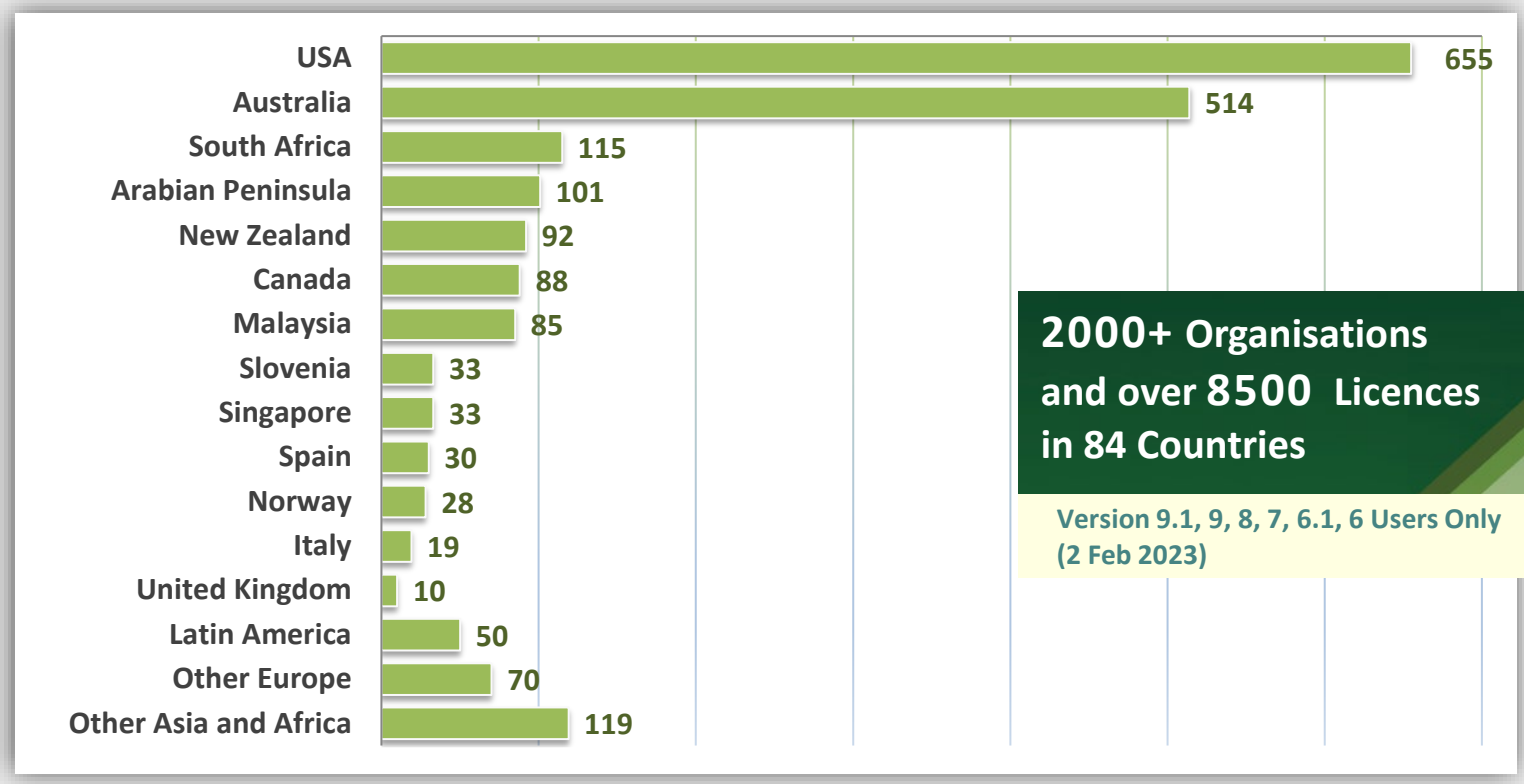
SIDRA INTERSECTION Users



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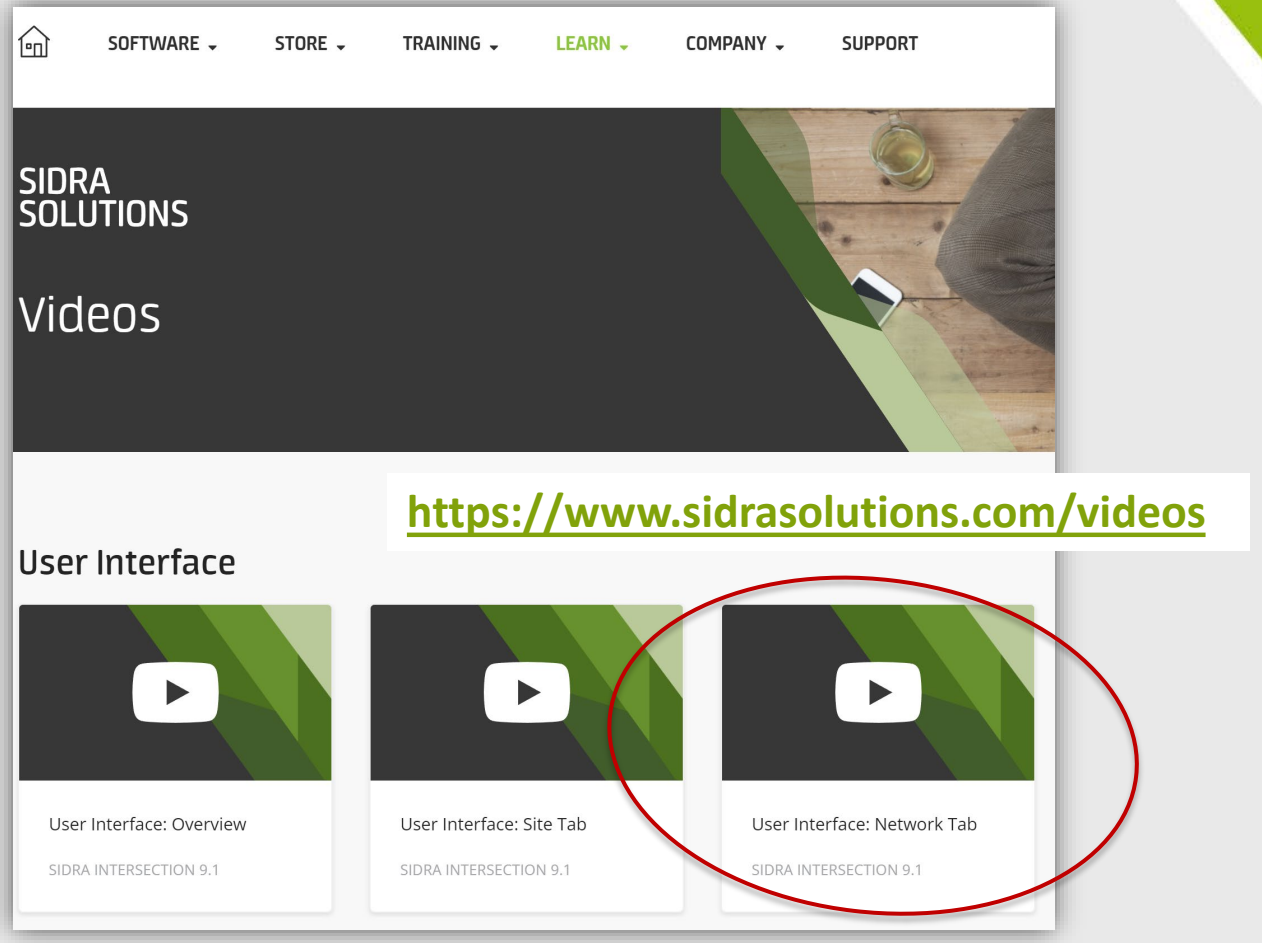
New Tutorial Video

New tutorial video updated for SIDRA INTERSECTION 9.1:

User interface: Network Tab



New SIDRA Training Workshops (In-Person) 2023

We have designed new programs for in-person (classroom) training.

- **SIDRA Advanced Workshop**
  New in-person (classroom) workshop for users of SIDRA INTERSECTION software.
- **SIDRA for Project Managers & Reviewers**
  For professionals who review SIDRA analyses rather than actually undertaking the analyses, as well as project managers who have little experience in modelling but make design and operation decisions based on review of SIDRA analyses.

Dates

- **SYDNEY | 28-31 March 2023**
- Brisbane | 11-14 July 2023
- Perth | 8-11 August 2023
- Melbourne | 22-25 August 2023

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SIDRA NETWORK MODEL

SIDRA Network Model

Lane-based micro-analytical model

For small to medium size networks (up to 50 Sites)

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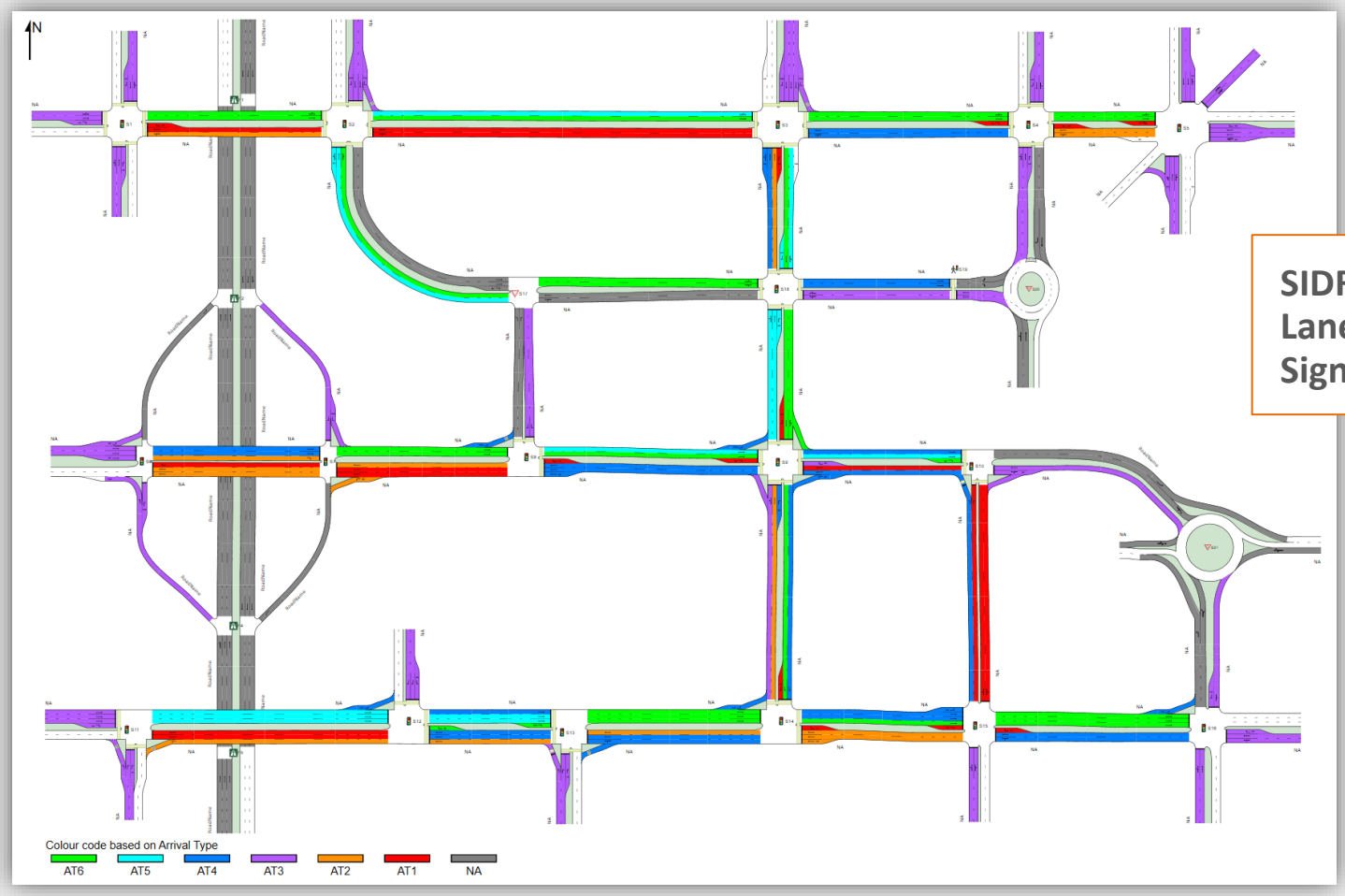
26-Site Network Example



SIDRA INTERSECTION 9.1
Lane Display:
Signal Coordination

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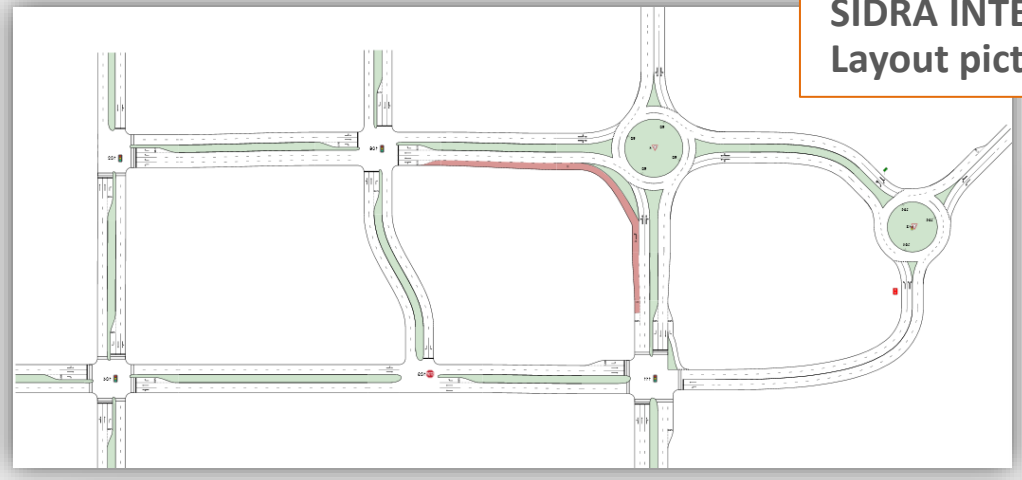
SIDRA NETWORK Model Features

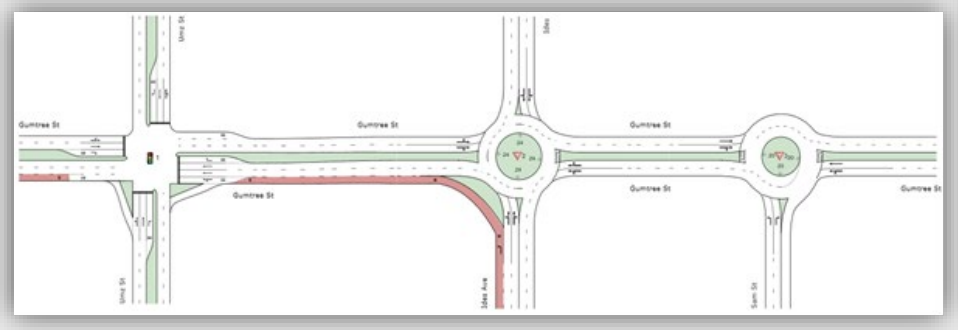
All intersection and crossing types, interchanges (signals, roundabouts, sign control)

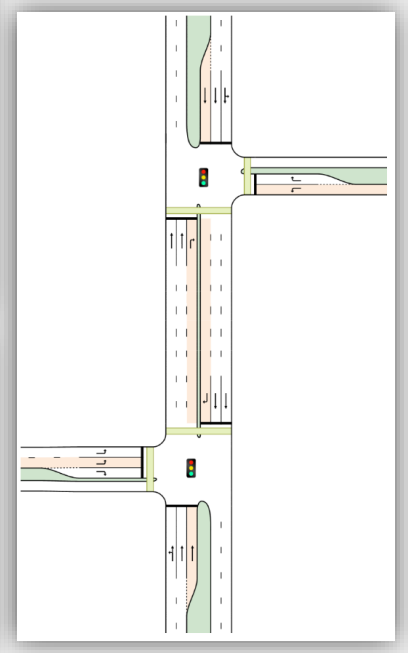
Paired Intersections

Alternative Intersections and Interchanges

SIDRA INTERSECTION 9.1
Layout pictures







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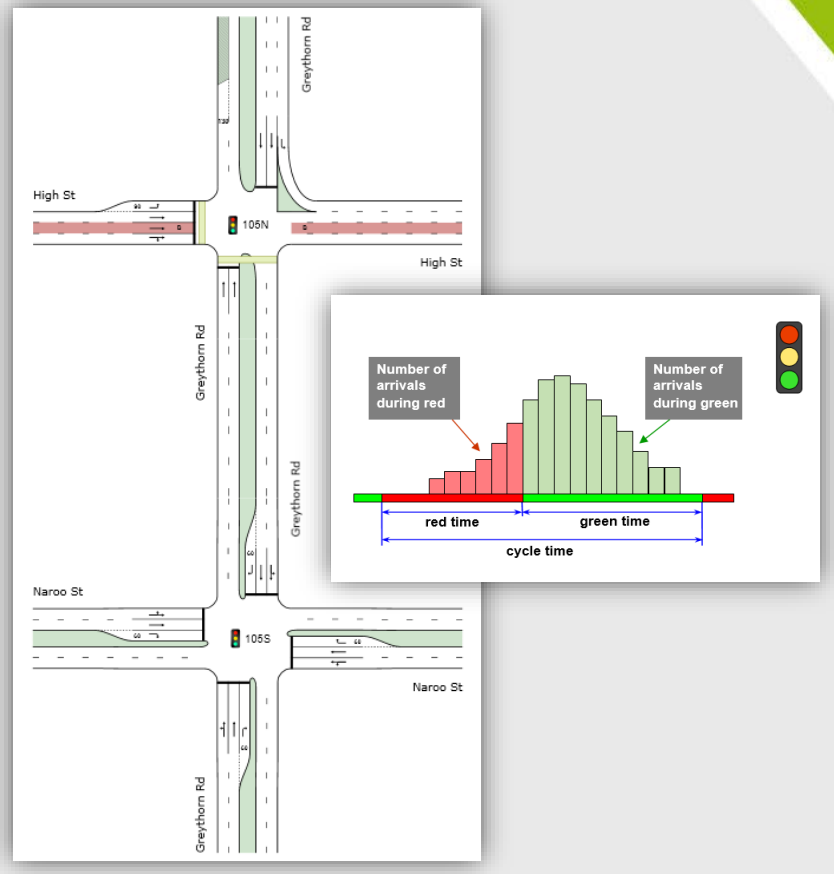
SIDRA NETWORK Model Features

- **LANE-BASED** analytical Network model
- **QUEUE SPILLBACK** and **Capacity Constraint**
- **Movement Classes**
  (special use for downstream turning movements)
- Second-by-second lane-based **platoon model**
- **Lane Movements** at intersections
- Implied **midblock lane changes**
- **Network signal timing**
  (**cycle time**, **green splits** and **offsets**
  for **signal coordination**)
- **Common Control Group** for signal phasing and timing with one signal controller unit



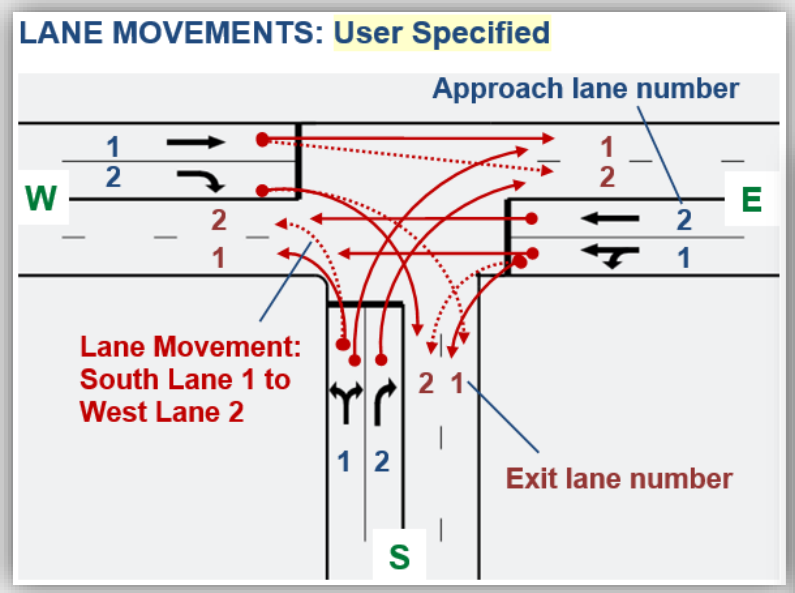
Lane Blockage and Capacity Constraint

Backward spread of congestion (reduced upstream capacity)

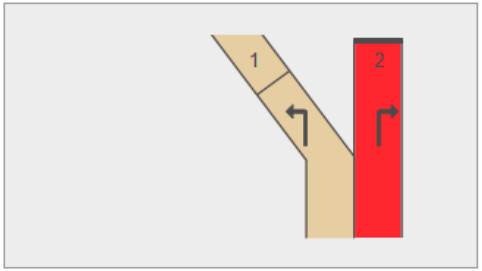
Capacity constraint (reduced downstream arrival flows)

- The two basic elements of the model are highly interactive with opposing effects.
- Requires an iterative process to find a solution that balances these opposing effects (some uncertainty for congested networks).
- Backward spread of congestion and capacity constraint are common to all intersection types.

Lane Movements by Movement Class



Lane Editor

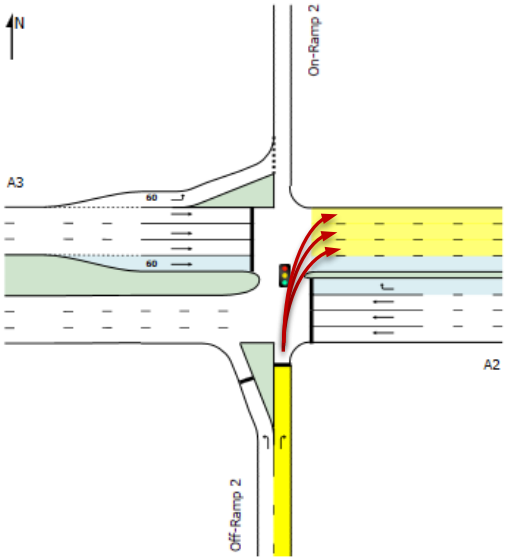


South Approach Lane 2

Lane Movement Flow Proportions

From South to Exit:	E
	R2
Exit Lane 1	33 %
Exit Lane 2	34 %
Exit Lane 3	33 %
Exit Lane 4	0 %

Freeway Off-ramp Lane Example



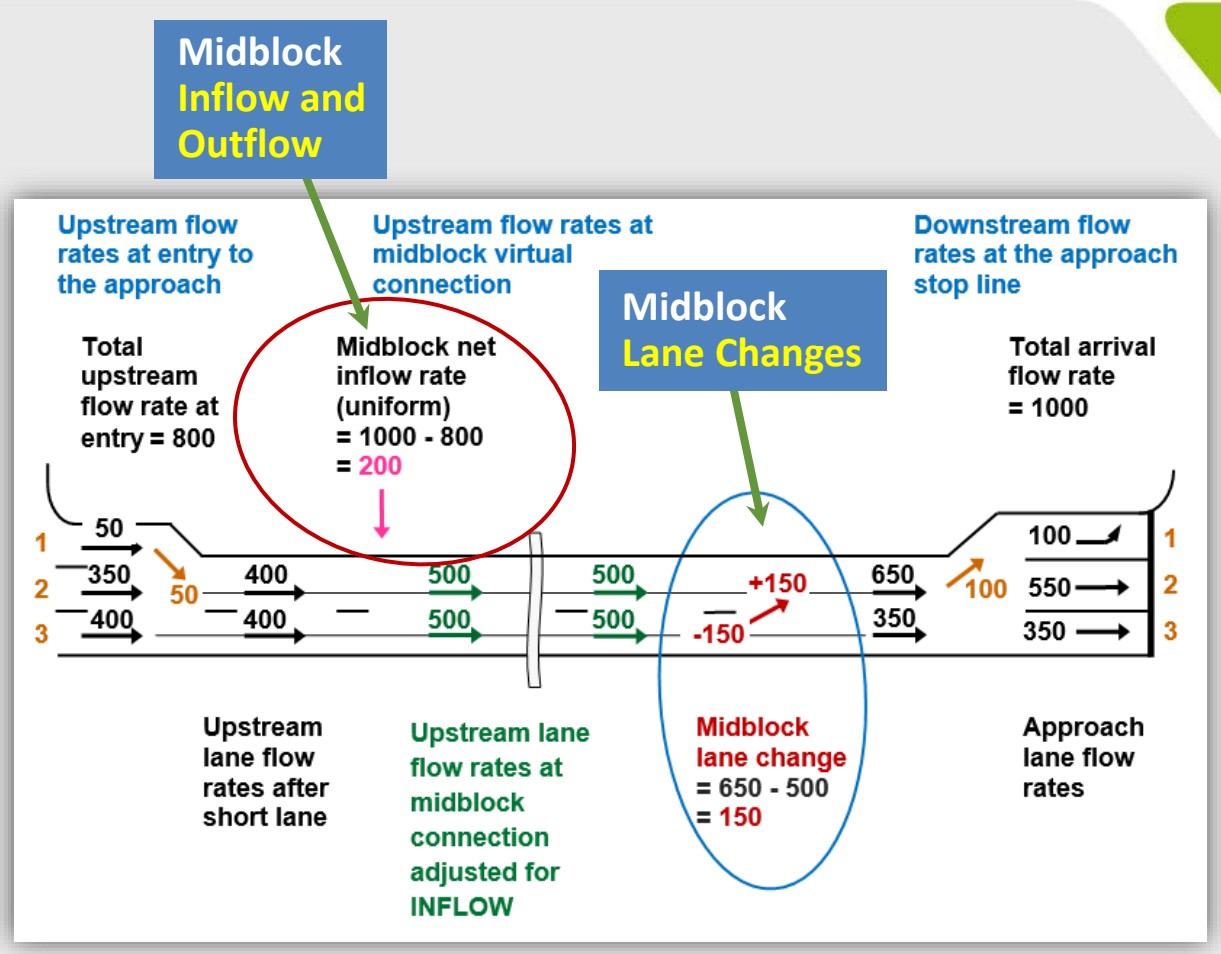
Midblock Lane Changes

Matching of Upstream and Downstream Lane Flow Rates:

- Implied midblock lane changes
- Effect of this on platoon arrival patterns at signals

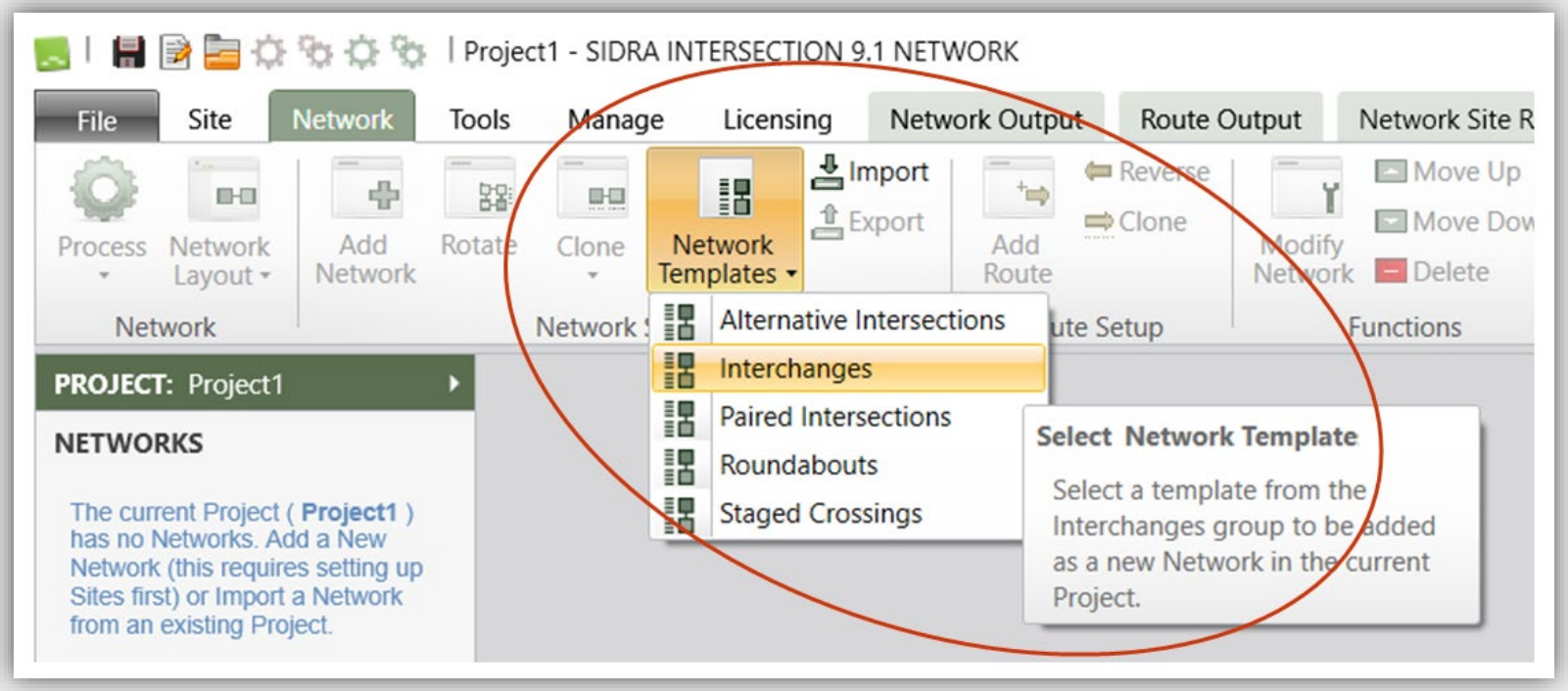
Tools to minimise midblock lane flow changes on short internal approaches:

- Special Movement Classes
- Lane Movement Flow Proportions
- Lane Utilisation Ratios



Network Templates

Network Templates are accessed using the Network Templates command menu in the Network tab ribbon.



SIDRA INTERSECTION Network Templates

Alternative Intersections

- Continuous Flow Intersection (CFI)
- P-Turn
- Restricted Crossing U-Turn (RCUT)

Roundabouts

- Double Teardrop Roundabout
- Roundabout with Bicycle Circle
- Roundabout with Signalised Pedestrian Crossings
- Roundabout with Unsignalised Pedestrian Crossings

Interchanges

- Divergabout Interchange
- Diverging Diamond Interchange (DDI)
- Double Roundabout Interchange
- Double Teardrop Roundabout Interchange
- Partial Cloverleaf (Parclo) Interchange
- Signalised Diamond Interchange (SDI)
- Unsignalised Diamond Interchange

Staged Crossings

- Four-Way Intersection Two-Stage Crossing
- Two-Stage T-Intersection Crossing (Types A and B)
- Unsignalised Wide-Median Intersection

For detailed information:
SIDRA INTERSECTION User Guide
Section 9.4

Paired Intersections

- Wide-Median Intersection Signals
- Fully Signalised Roundabouts
- Staggered T Signals
- Staggered T Unsignalised

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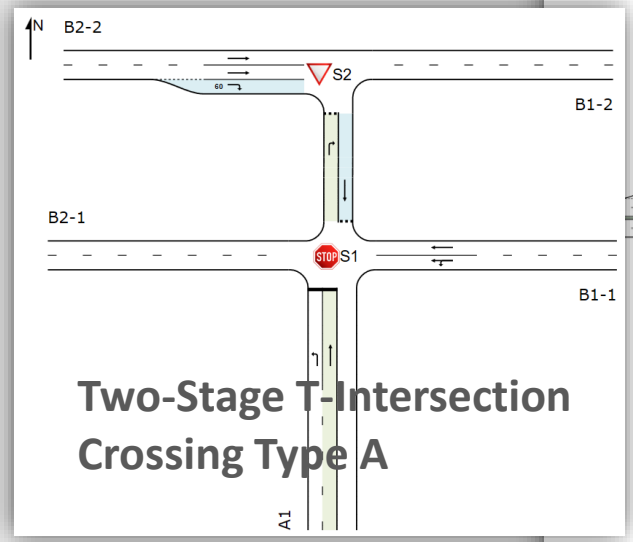
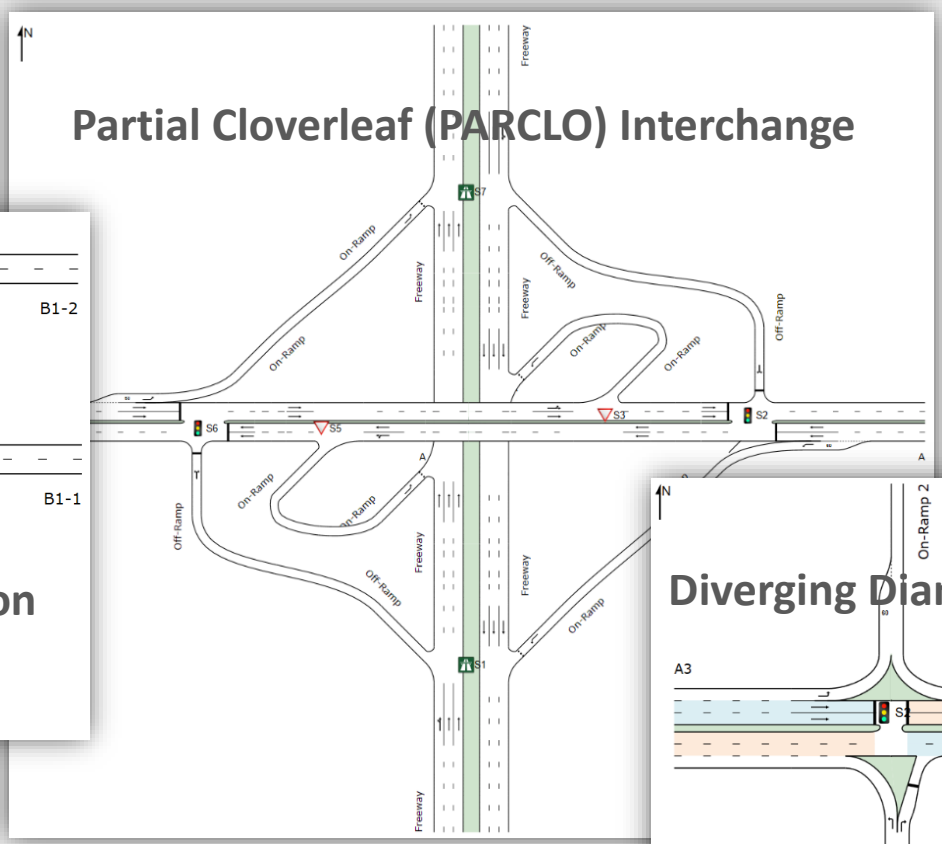
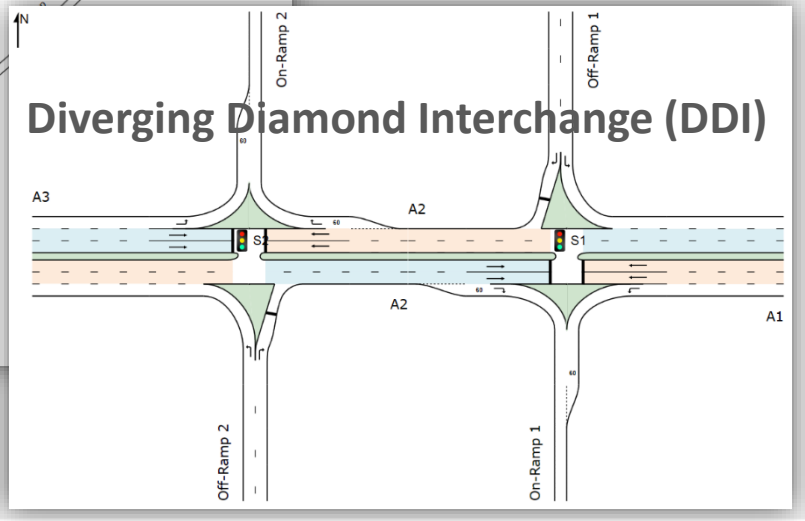
Network Template Examples



Two-Stage T-Intersection Crossing Type A



Partial Cloverleaf (PARCLO) Interchange



Diverging Diamond Interchange (DDI)

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SIDRA Network Model Demo

Signal Coordination Lane Display for Network Routes

Variable Demand Model for Congestion Modelling - The SIDRA Method

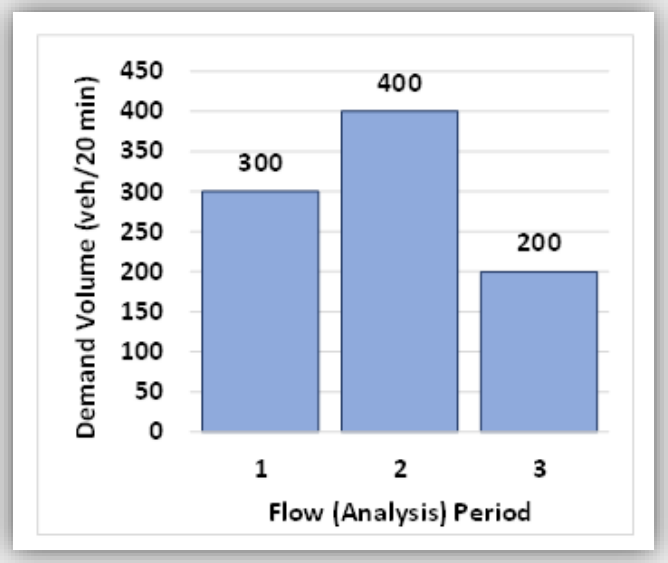
What is Variable Demand Modelling?

The Variable Demand Model is useful for multi-period analysis of persistent congestion.

The model uses the Initial Queued Demand in estimating delays, queue lengths and stop rates when sequential flow periods are analysed in cases of congested conditions.

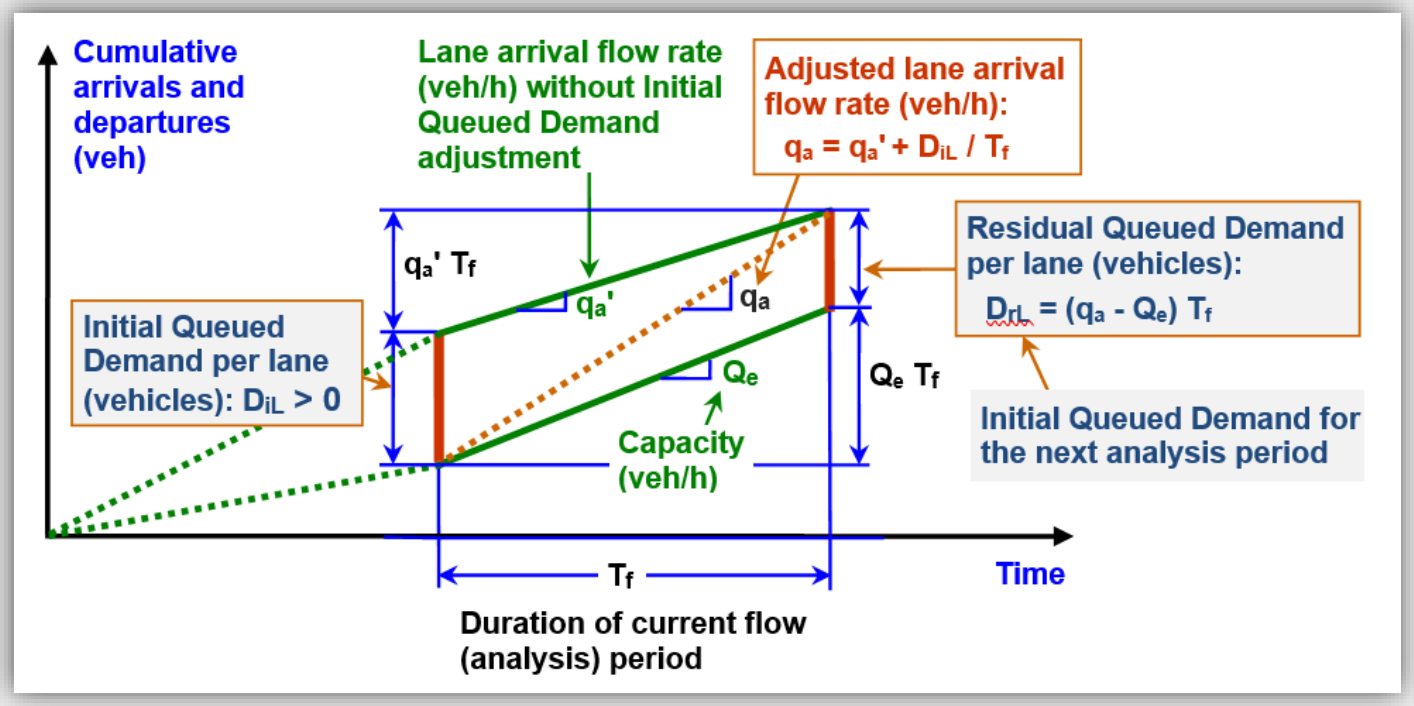
Initial Queued Demand is the Residual Queued Demand left over from the previous flow (analysis) period when a lane is oversaturated (arrival flow exceeds capacity).

This is shown in the next slide.



Initial and Residual Queued Demand

Deterministic queuing theory is used to formulate a **deterministic oversaturation delay function**. **Initial Queued Demand**, **Residual Queued Demand** and **Adjusted Arrival Flow Rate** are shown here.

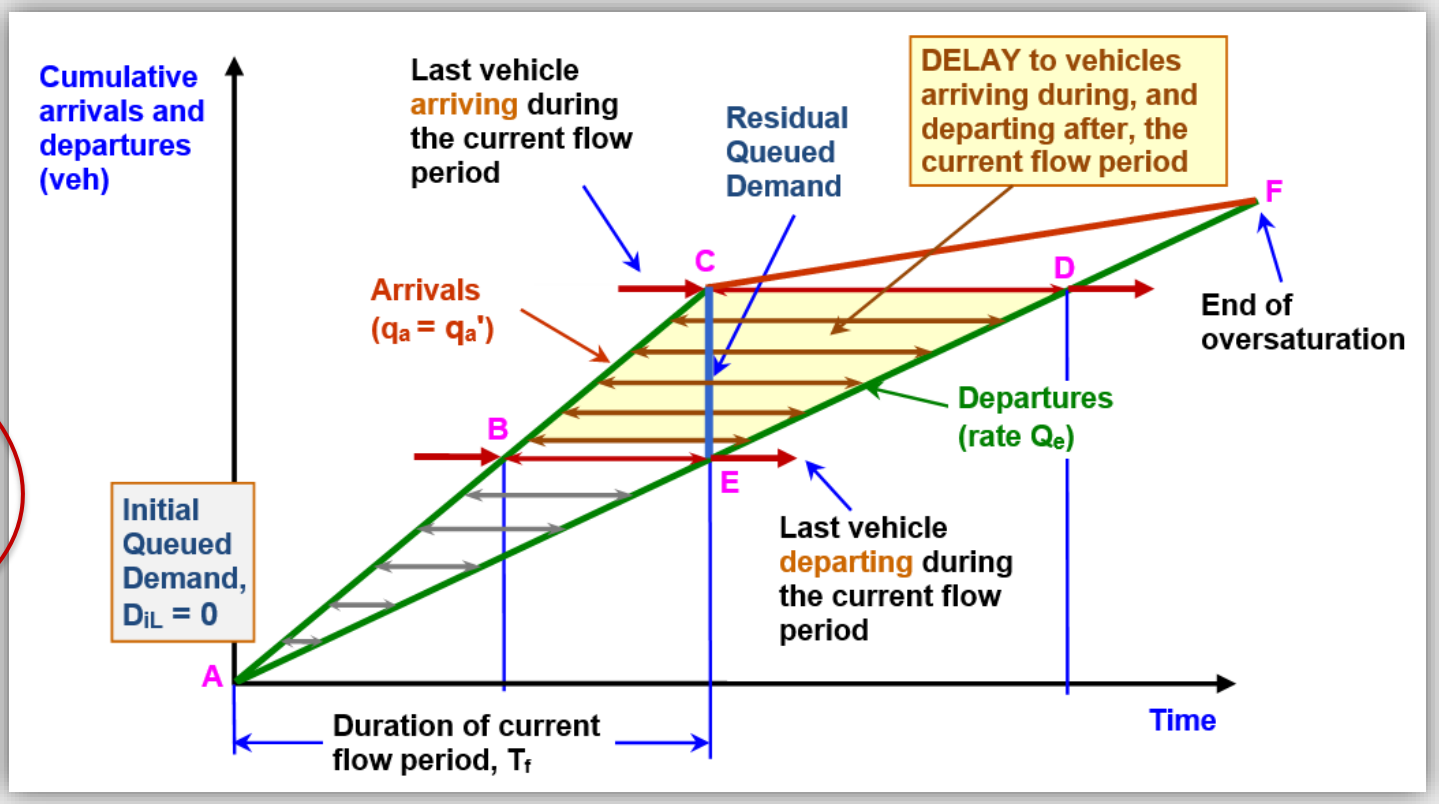


Delay experienced by vehicles in oversaturated conditions: No Initial Queued Demand

Deterministic Oversaturation Delay Model
With No Initial Queued Demand

In SIDRA, delay experienced by vehicles departing after the analysis period is included.

This corresponds to in-stream travel time survey method.



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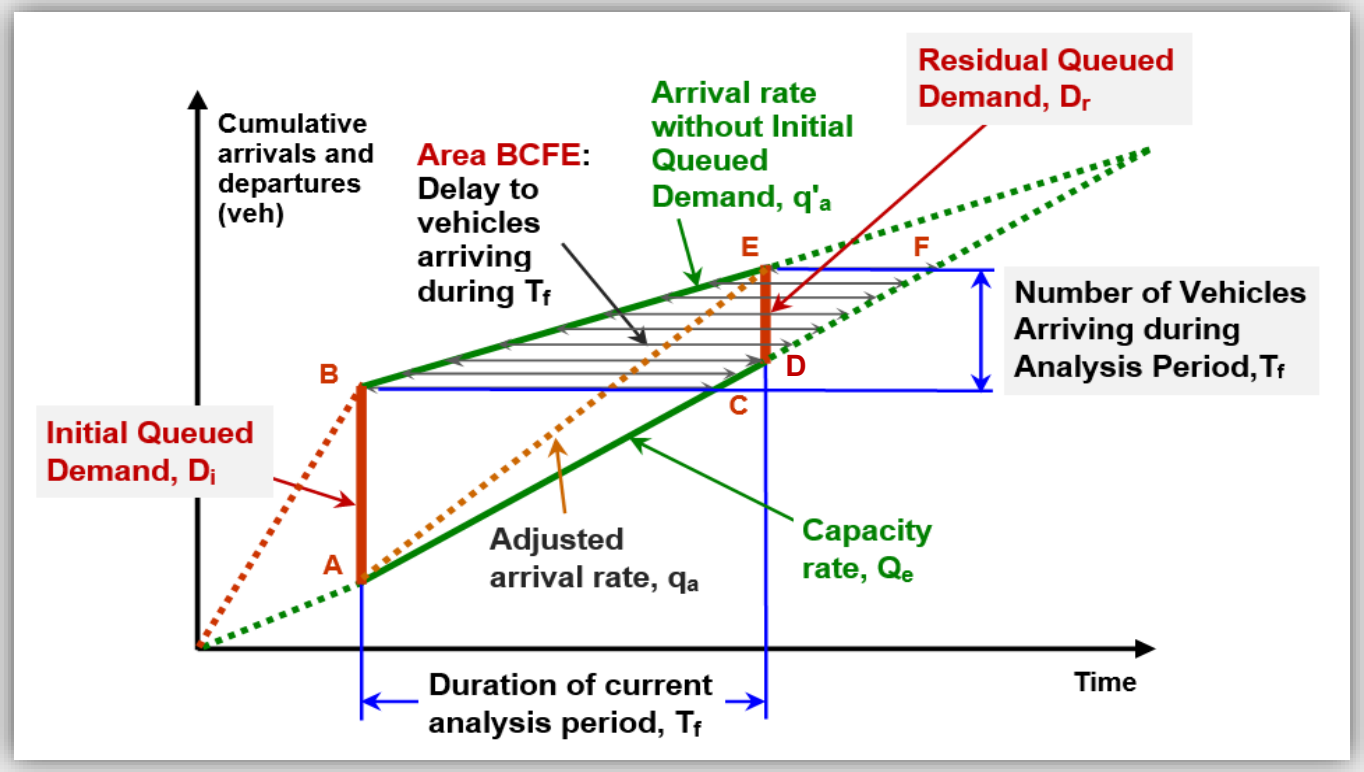
Delay experienced by vehicles in oversaturated conditions

Area ABC: Delay experienced by vehicles arriving before the current flow period (forming the Initial Queued Demand) and departing during the current period; included in delay estimated for the previous flow period.

Area DEF: Delay experienced by vehicles arriving during the current flow period and departing after the current period.

Area BCFE: Delay to vehicles arriving during the current flow period.

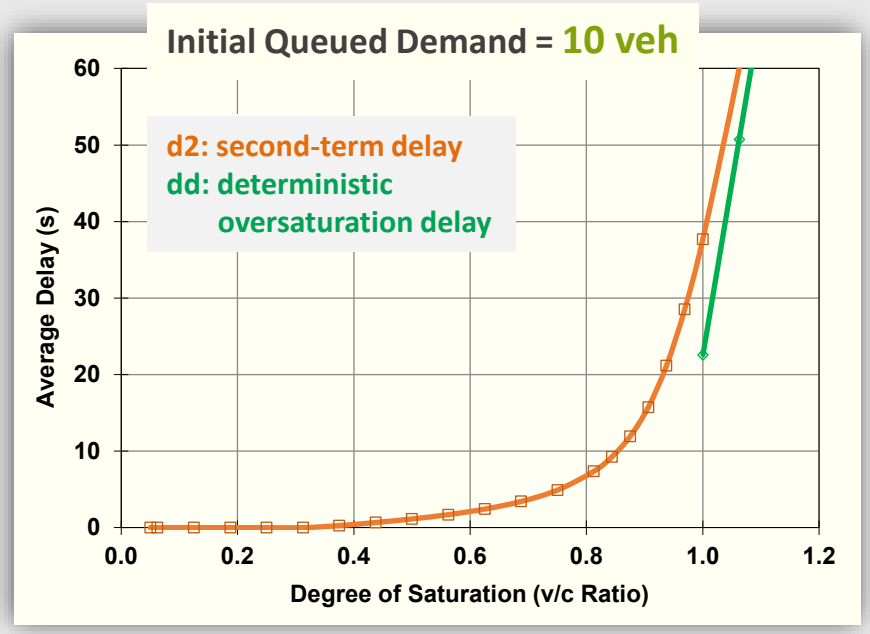
Deterministic Oversaturation Delay Model With Initial Queued Demand

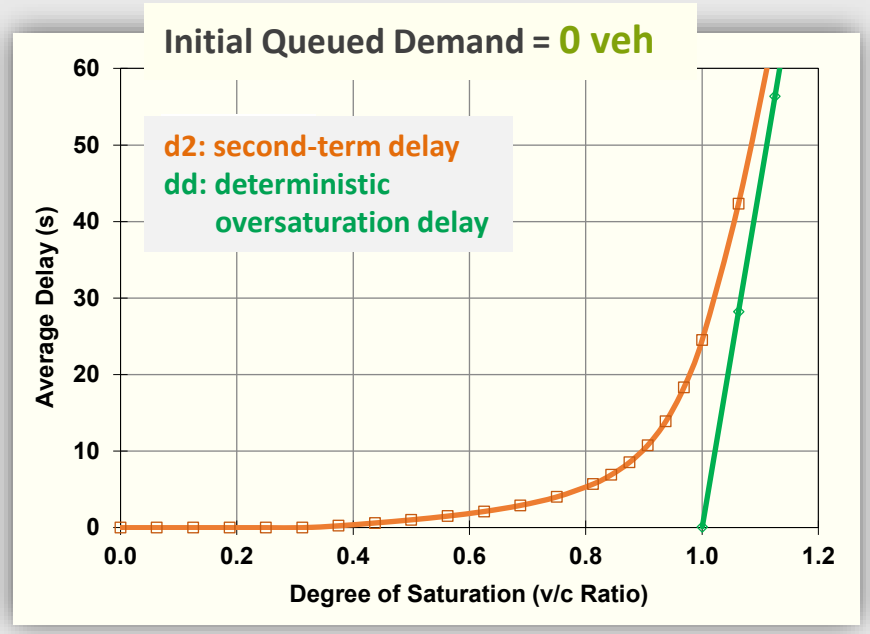


Delay function using the *coordinate transformation technique*

New two-term performance functions have been derived for the Variable Demand Model used in SIDRA INTERSECTION 9.1 using the **coordinate transformation technique**.
In this method, the **second-term delay function** (time-dependent congestion term) is asymptotic to the **deterministic oversaturation delay function**.

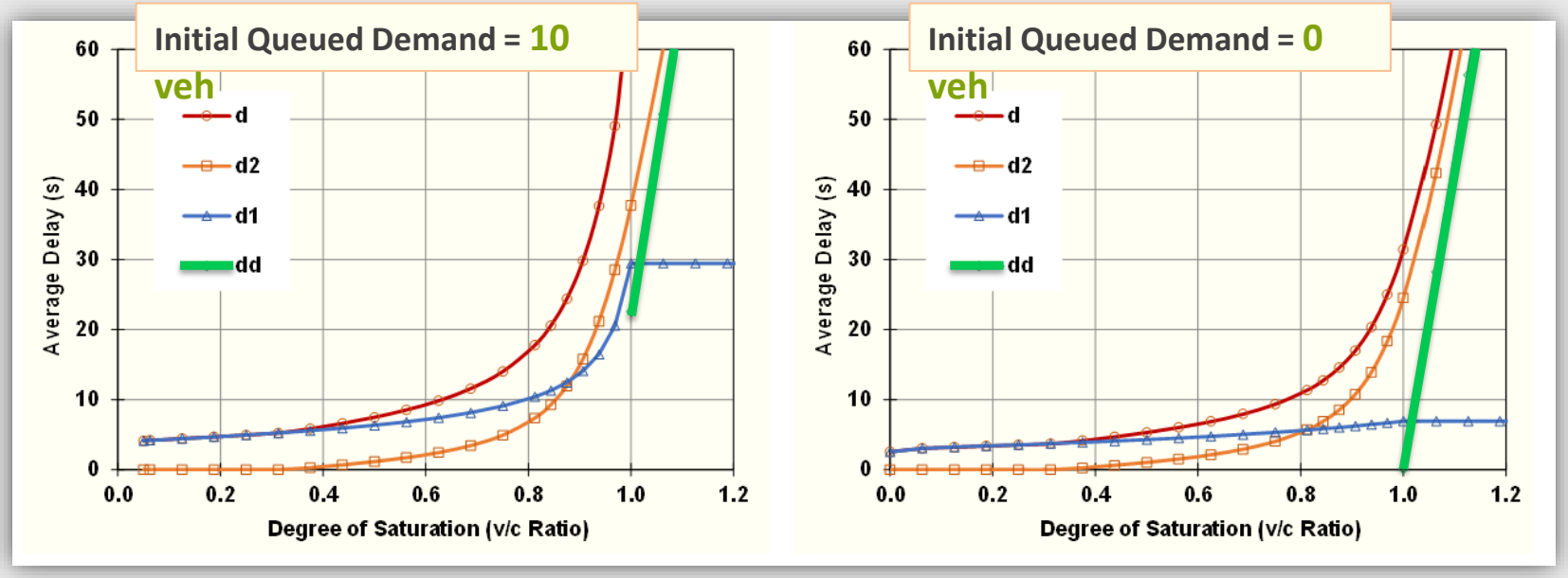
This is the technique used for deriving the models given in **ARR 123** (Akçelik 1981).





Two-term Performance Function

Example of delay function for a roundabout case with and without Initial Queued Demand (Capacity = 800 veh/h, Flow Period = 0.25 h)



d = d1 + d2: average control delay
d1: first-term delay (red time or blocked time effect)
d2: second-term delay (congestion effect)
dd: deterministic oversaturation delay

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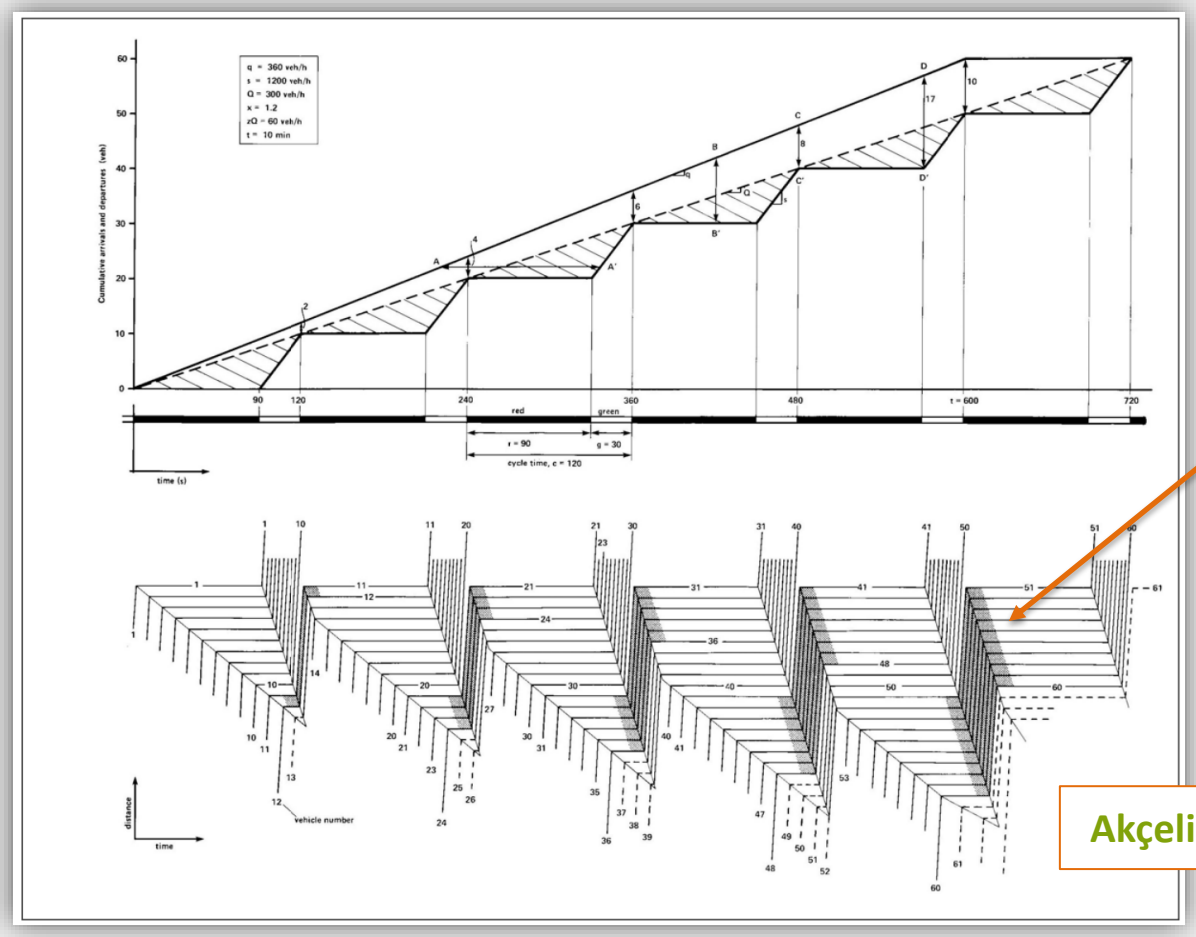
Deterministic queuing theory for oversaturation delay and back of queue



Overflow Queues are used in SIDRA performance models

Akçelik (1980)

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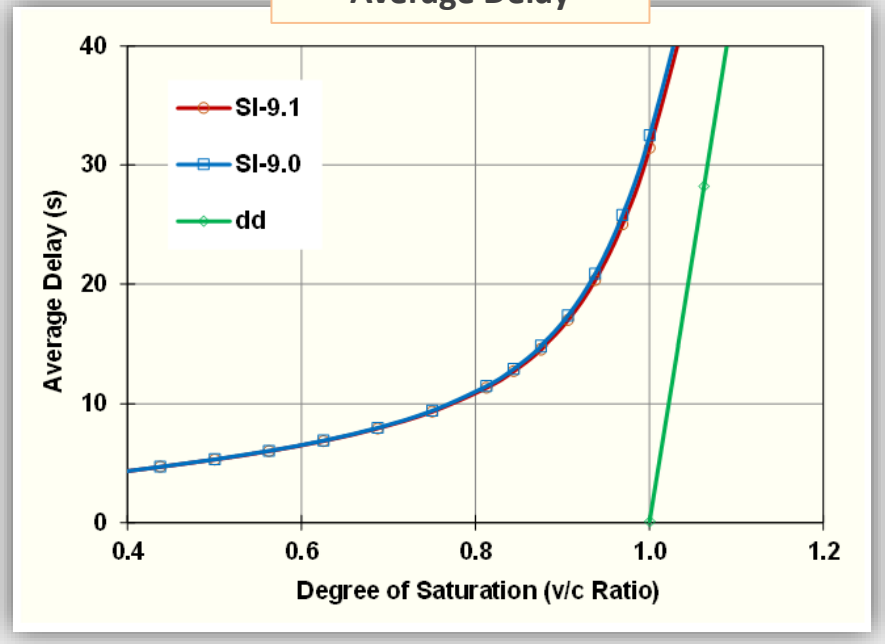
Small difference in SIDRA INTERSECTION Version 9.1 and older versions

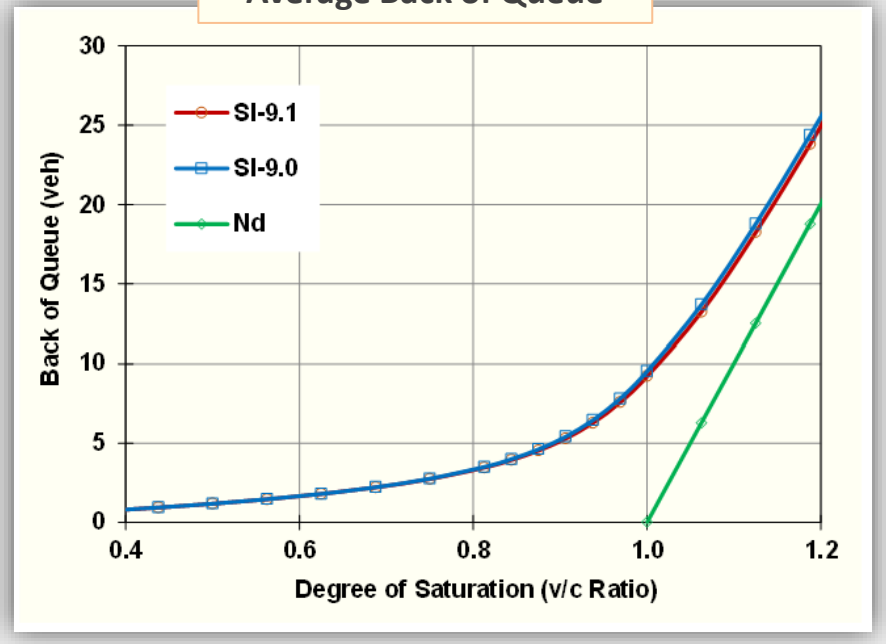
Small difference in delay and back of queue estimates in **SIDRA INTERSECTION Version 9.1 and older versions**

Example for Initial Queue Demand = 0

Average Delay

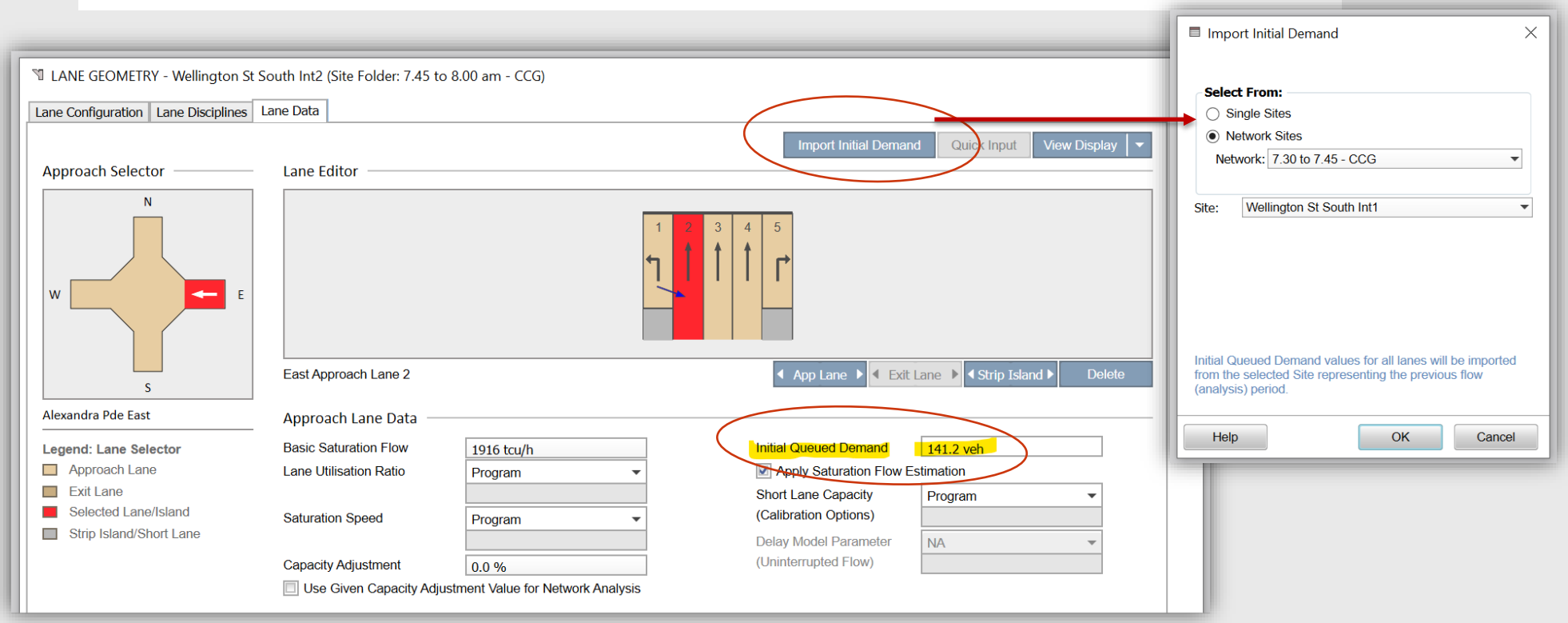


Average Back of Queue



Initial Queued Demand input in SIDRA INTERSECTION 9.1

Import Initial Demand function is used to copy Residual Queued Demand values from the Site representing the previous (15-min) flow period as the Initial Queued Demand values for the current Site



Variable Demand Model Basic Example

Variable Demand Model Example for a Basic Network

		Site 1	Site 2	Site 3	Route
Travel Distance	m	1000	1000	2000	4000
Cruise Speed	km/h	72	72	72	72
Cruise Travel Time	sec	50.0	50.0	100.0	200.0

Variable Demand Model Example for a Basic Network with three 20-min flow periods

This example shows the complexity added to the variable demand model for Networks due to Capacity Constraint requirements.

Three consecutive 20-min flow periods analysed for a simple network of three Sites.

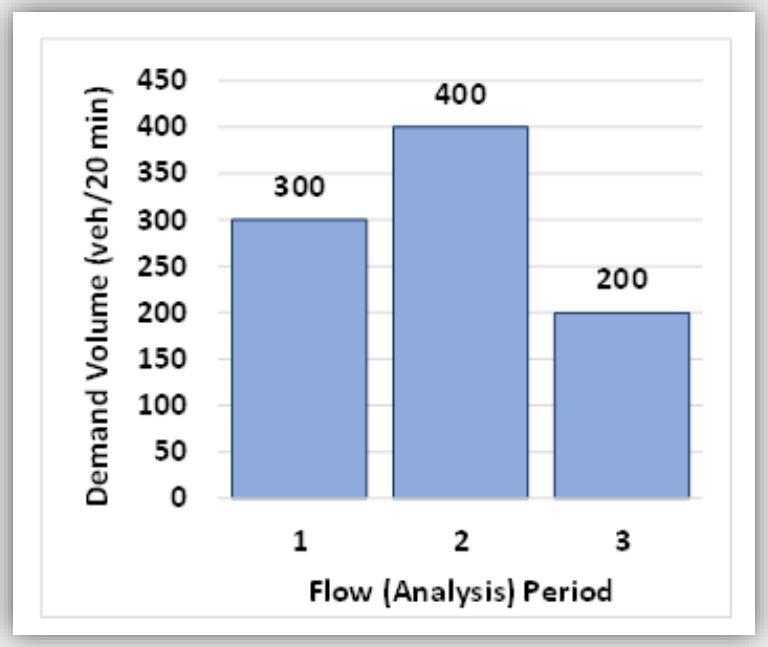
Average Flow Rate per hour: 900 veh/h

Peak Flow Rate per hour (Period 2):

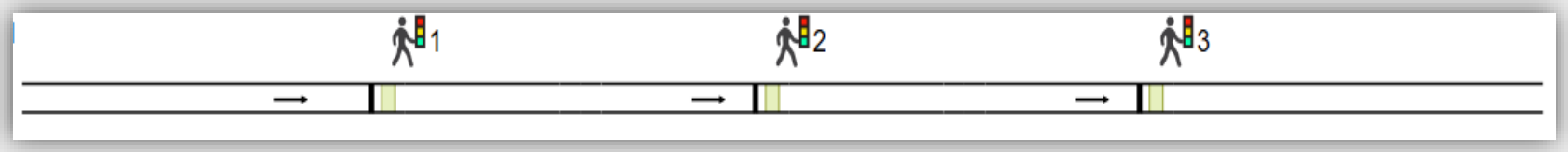
(60/20) x 400 = 1200 veh/h

Peak Flow Factor:

PFF = 900/1200 = 0.75 (a high peaking value)

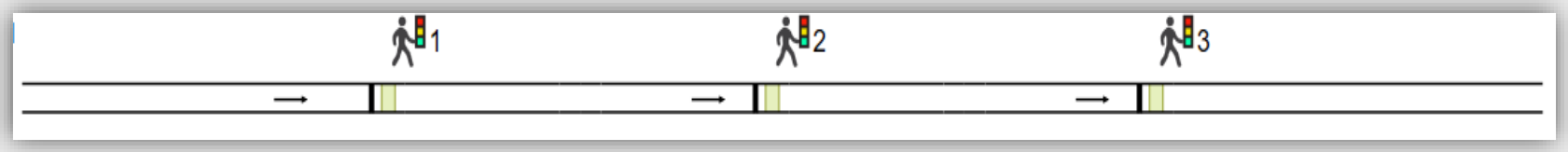


Basic Network - Analysis Period 1



Analysis Period 1		Site 1	Site 2	Site 3	Route
Input Volume (Demand)	veh/20 min	300	300	300	
Number of Vehicles Arriving	veh	300	300	300	
Capacity	veh	400	300	300	
Initial Queued Demand	veh	0	0	0	
Vehicles Arriving + Initial Queued Demand	veh	300	300	300	
Number of Vehicles Departing	veh	300	300	300	
Residual Queued Demand	veh	0	0	0	
SIDRA Average Travel Time	sec	65.5	114.2	164.2	343.9

Basic Network - Flow Period 2



Analysis Period 2		Site 1	Site 2	Site 3	Route
Input Volume (Demand)	veh/20 min	400	400	400	
Number of Vehicles Arriving	veh	400	340	300	
Capacity	veh	340	300	240	
Initial Queued Demand	veh	0	0	0	
Vehicles Arriving + Initial Queued Demand	veh	400	340	300	
Number of Vehicles Departing	veh	340	300	240	
Residual Queued Demand	veh	60	40	60	
SIDRA Average Travel Time	sec	196.1	176.0	295.6	667.7

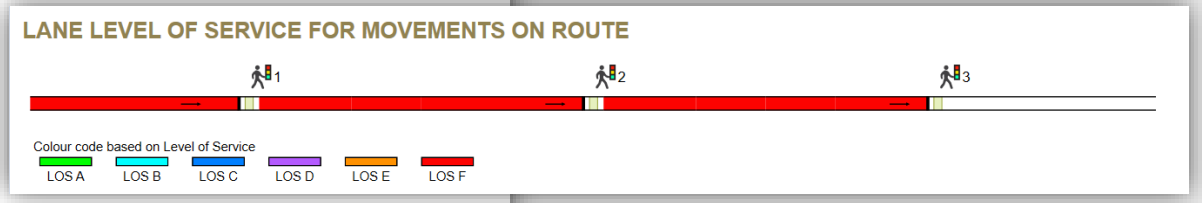
Basic Network - Flow Period 3

Analysis Period 3		Site 1	Site 2	Site 3	Route
Input Volume (Demand)	veh/20 min	200	200	200	
Number of Vehicles Arriving	veh	200	260	300	
Capacity	veh	580	580	580	
Initial Queued Demand	veh	60	40	60	
Vehicles Arriving + Initial Queued Demand	veh	260	300	360	
Number of Vehicles Departing	veh	260	300	360	
Residual Queued Demand	veh	0	0	0	
SIDRA Average Travel Time	sec	51.5	51.6	101.9	205.0

Variable Demand Model Basic Example Demo

Route Travel Performance

Performance Measure	Vehicles:	All MCs (Route)	Persons
Travel Speed (Average)	km/h	21.6	21.6
Travel Distance (Average)	m	4000.0	4000.0
Travel Time (Average)	sec	667.8	667.8
Desired Speed	km/h	72.0	
Route Delay (Average)	sec	467.8	467.8
Route Stop Rate		5.35	5.35
Route Level of Service (LOS)		LOS F	
Speed Efficiency		0.30	
Travel Time Index		2.22	
Congestion Coefficient		3.34	



Route Travel Movement Performance

Mov ID	Turn	Mov Class	Trav Dist m	Midbl. Delay sec	Trav Time sec	Aver. Speed km/h	Aver. Delay sec	Prop. Queued	Eff. Stop Rate	Aver. No. of Cycles	Dem. Flow Rate veh/h	Arv. Flow Rate veh/h	Deg. of Satn
Site ID: 1 Site Name: Site1 Intv2 Di=0 Dr=60													
West Approach													
2	T1	All MCs	1000.0	0.0	196.1	18.4	146.1	1.00	1.81	2.02	1200	1200	1.176
Site ID: 2 Site Name: Site2 Intv2 Di=0 Dr=40													
West Approach													
2	T1	All MCs	1000.0	0.0	176.0	20.5	126.0	1.00	1.65	1.87	1200	1020	1.133
Site ID: 3 Site Name: Site3 Intv2 Di=0 Dr=60													
West Approach													
2	T1	All MCs	2000.0	0.0	295.6	24.4	195.6	1.00	1.89	2.31	1200	900	1.250

Arrival Flows used in performance calculations are adjusted to include any Initial Queued Demand and Upstream Capacity Constraint effects.

Variable Demand Model Example for a Basic Network: Route Travel Performance report for Flow Period 2 (Peak period)

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Alexandra Parade Corridor Congestion

Alexandra Parade Corridor Congestion

As real-life case study during morning peak period in Melbourne

Traffic congestion is concentrated along particular routes *(Terrill and Batrouney 2017)*

Alexandra Parade Corridor Case

Looking East and showing the Eastern Freeway Westbound approach at 8 am on 19 Sep 2012 *(Lay 2019)*

Alexandra Parade Corridor Case

Queues extending from the Hoddle St and Wellington St intersections onto the Eastern Freeway during AM peak *(Yumlu, Moridpour, Akçelik 2014)*

Queue from Hoddle St intersection

Queue from Alexandra Pde intersection

Westbound traffic

Alexandra Pde - Wellington St Intersection (previous study)

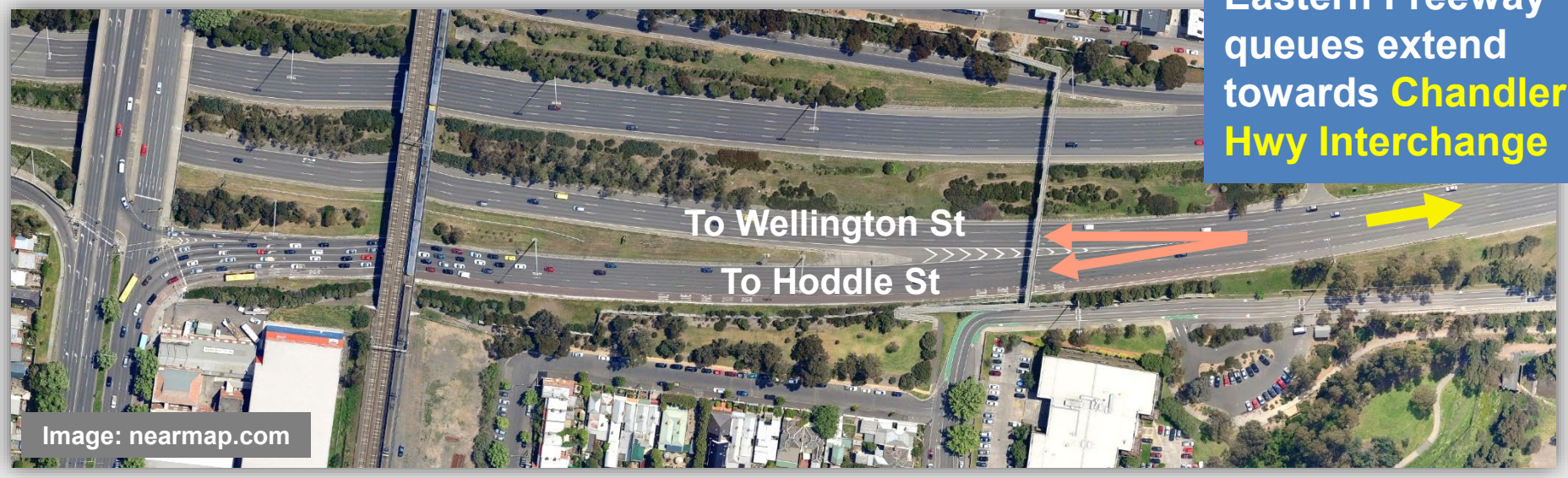
Wide-median intersection
(Yumlu, et al 2014)

Westbound traffic

Eastern Freeway

Eastern Freeway section upstream of Wellington St and Hoddle St intersections

Westbound traffic



In am peak period, Eastern Freeway queues extend towards Chandler Hwy Interchange

Alexandra Parade Intersections with Wellington St & Smith St

Wide-Median Intersections
modelled as Common Control Group (CCG)

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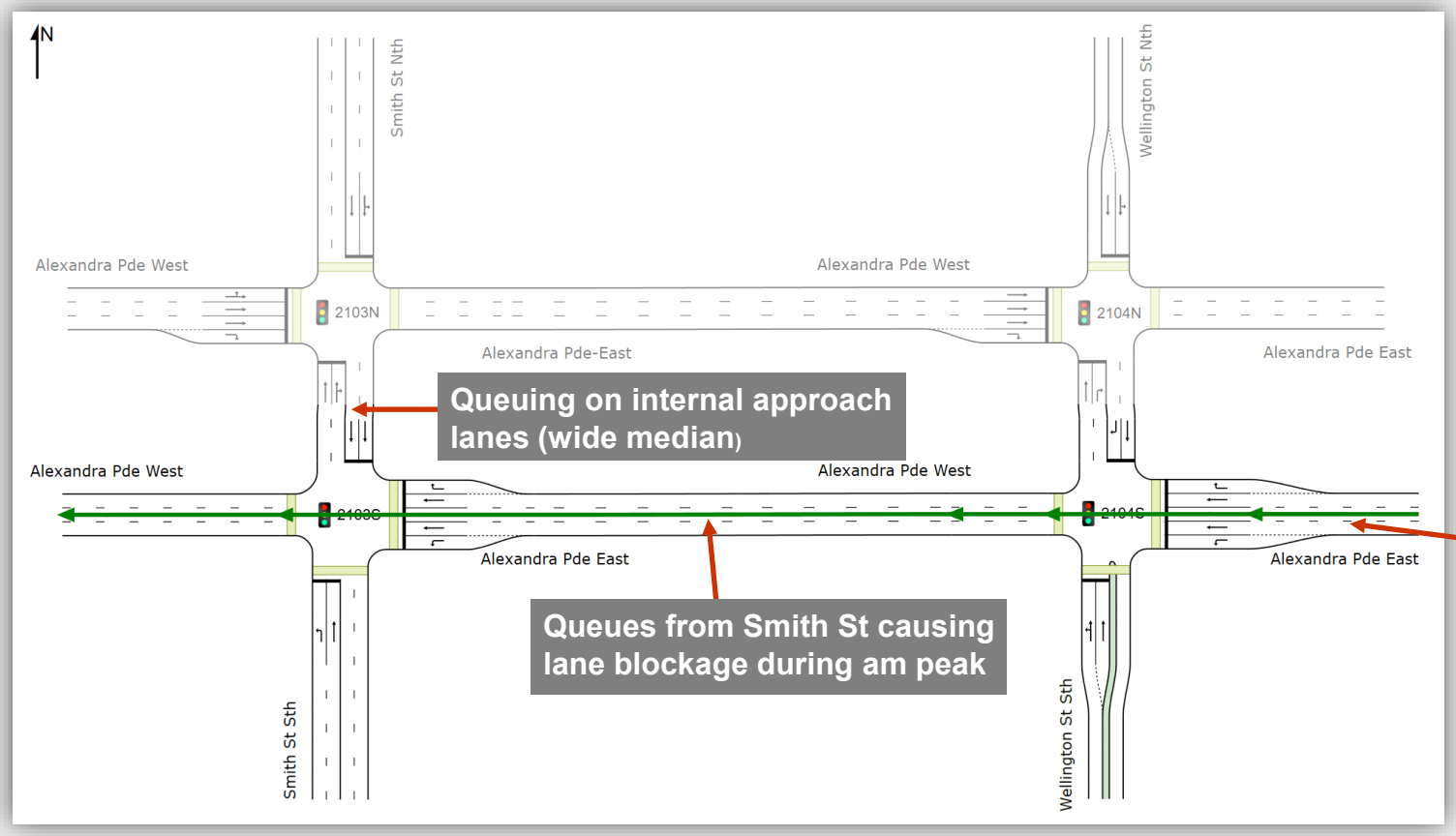
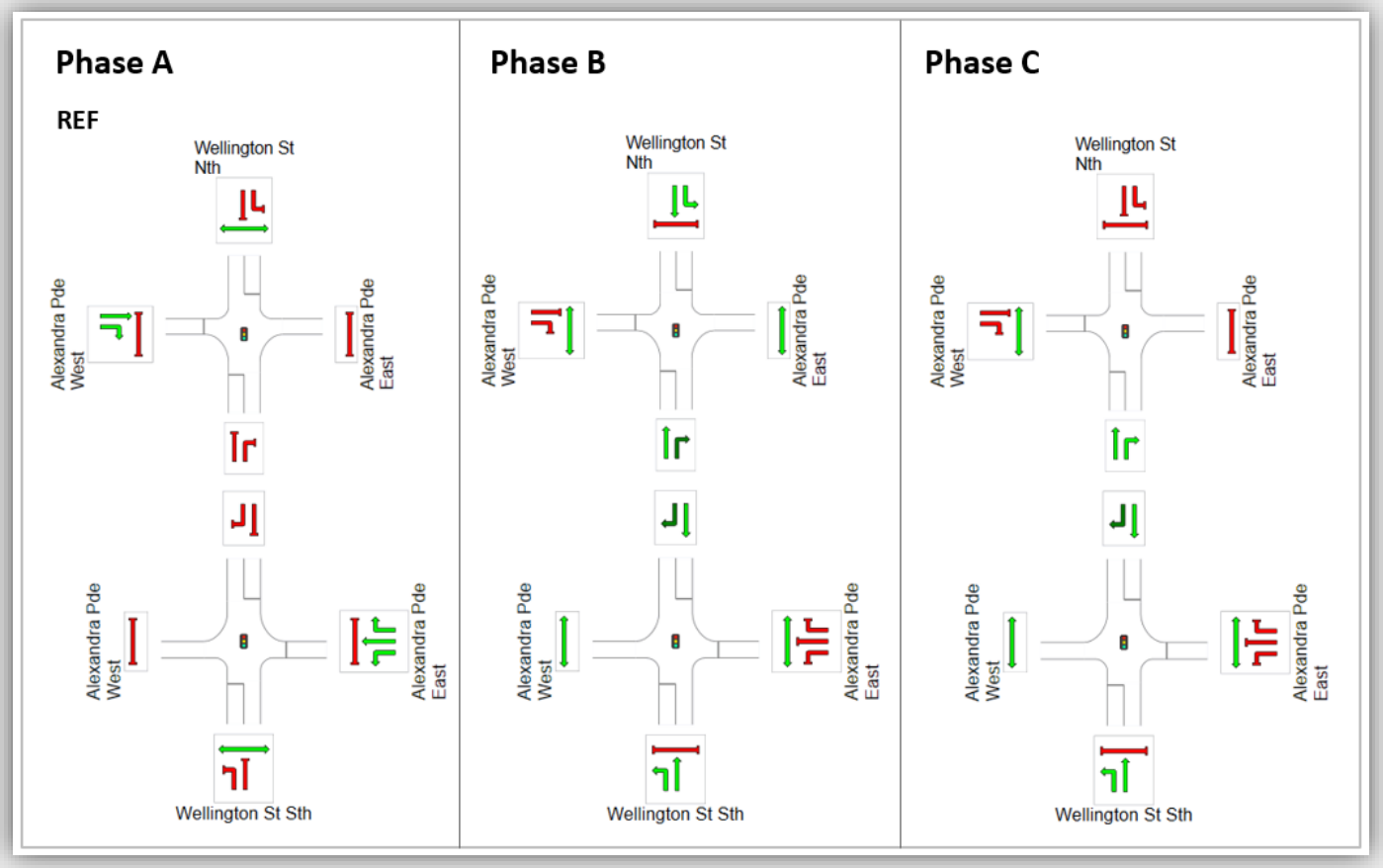
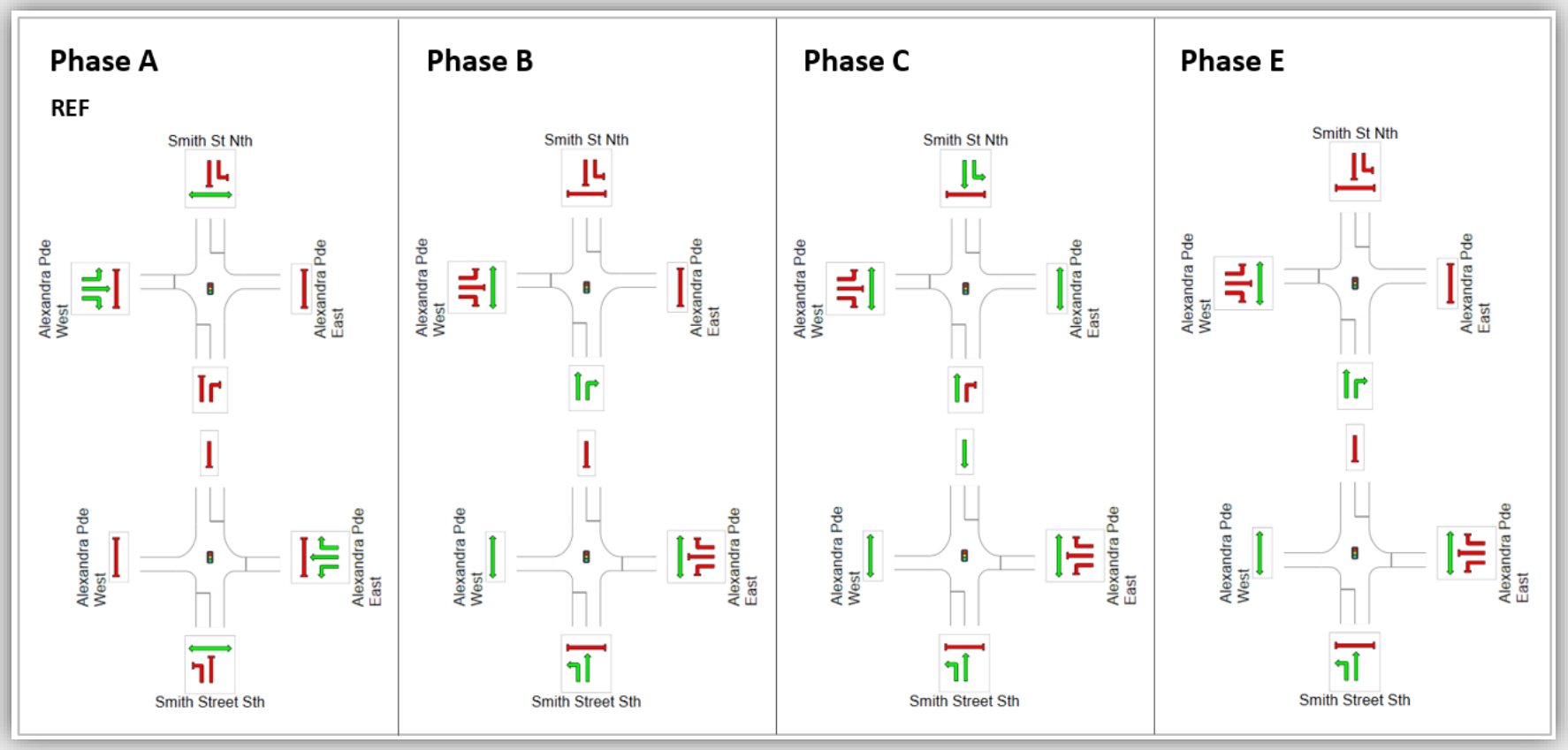
Westbound Route in focus



Signal Phasing for Wellington St and Alexandra Pde



Signal Phasing for Smith St and Alexandra Pde



Observed (User-specified) Phase Times and Offsets

Cycle time: 160 s

	Phase A (Reference Phase)	Phase B	Phase C	Phase D	Offset	
Alexandra Pde -Wellington St	110	40	10	-	0	Reference Site
Alexandra Pde - Smith St	92	16	40	12	-18	

Timing values in seconds

SCATS timing and volume data provided by VicRoads.

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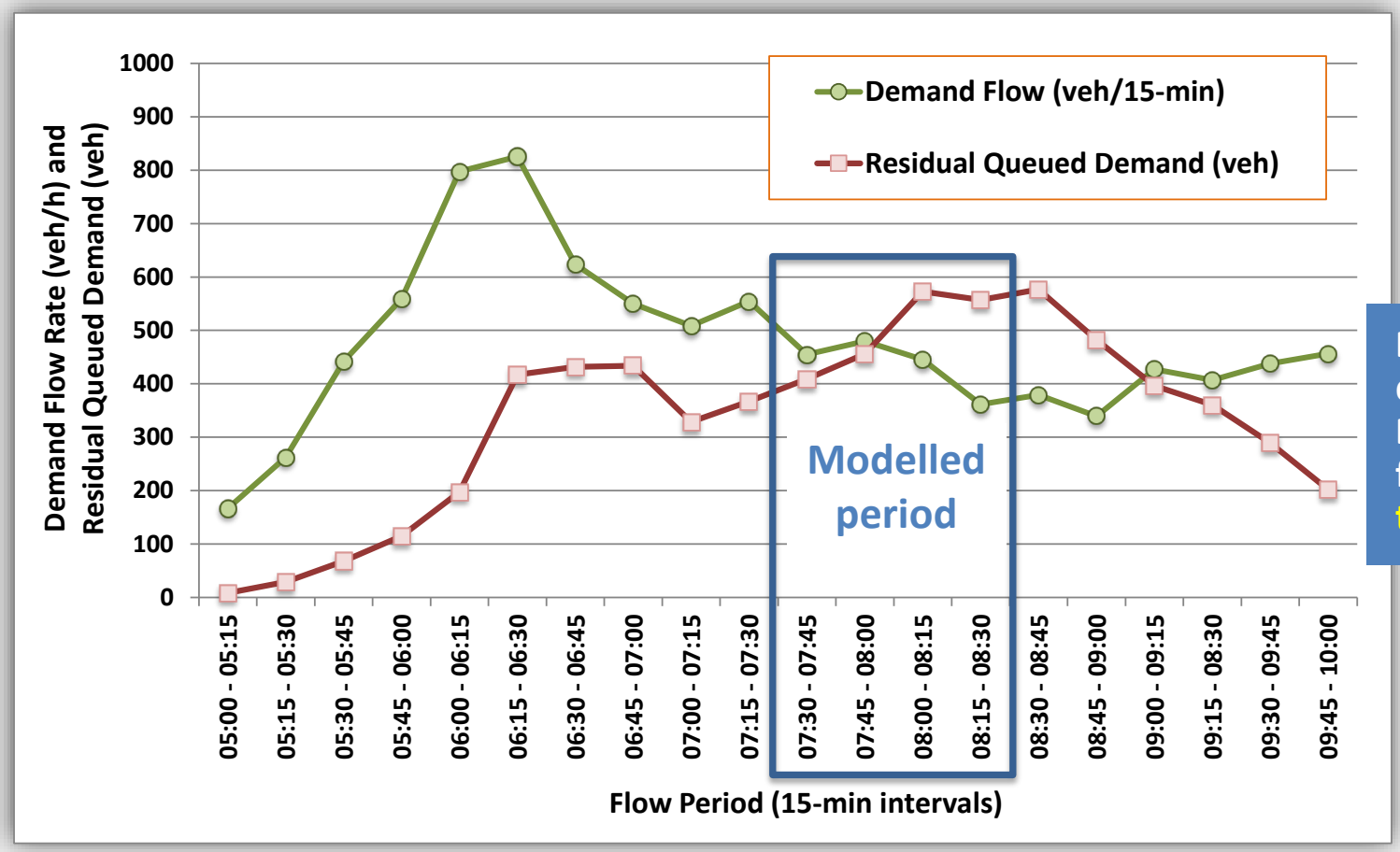
Previous study

Previous study (*Yumlu, Moridpour, Akçelik 2014*) reported the analysis of a single Site (Alexandra Pde - Wellington St intersection) and a single peak period (7.45 - 8.00 am).

In the current study:

- A Network model of Alexandra Pde intersections with Wellington St and Smith St. Signals are coordinated.
- 15-min demand flow rates starting at 5.00 am on 5 March 2014 were used to determine the Residual Queued Demand profile.
- Variable Demand Model was applied to four 15-min flow intervals for the 7.30 - 8.30 am flow period. This was used to determine the Initial Queued Demand at the start of 7.30 am peak period (367 veh).
- Results are presented for the 7.45 - 8.00 am period (observed and estimated Back of Queue values compared).

Demand Flow ad Residual Queued Demand "*observed*" for East approach of the Alexandra Pde - Wellington St intersection



Volume data provided by VicRoads.

Demand Flow Rate determined from Eastern Freeway flows upstream of the queued traffic

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Key model inputs for calibration

Intersection Approach	Alexandra Pde - Wellington St East Approach			Alexandra Pde - Smith St East Approach		
Lane	2	3	4	2	3	4
Basic Saturation Flow (veh/h)	1916	1813	1685	1800	1800	1800
Capacity Adjustment	Program	Program	Program	-50%	-50%	-50%
Initial Queued Demand for the first interval (7.30 to 7.45 AM)	123 veh	122 veh	122 veh	0	0	0

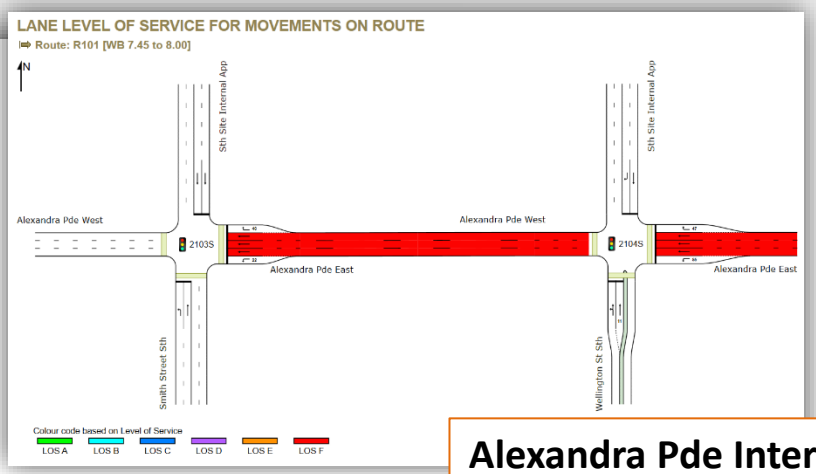
Saturation Flow surveys done at the intersections.

SIDRA model estimates of Initial Queued Demand and Back of Queue

Analysis Interval	Residual Queued Demand (veh)		Back of Queue (km)			
			Average		98th Percentile	
	Observed	Estimated	Observed	Estimated	Observed	Estimated
7.15 to 7.30 AM	367	-	-	-	-	-
7.30 to 7.45 AM	409	410	-	1.6	-	2.6
7.45 to 8.00 AM	456	522	2.5	1.9	3.5	3.2
8.00 to 8.15 AM	573	608	-	2.5	-	4.1
8.15 to 8.30 AM	557	611	-	2.7	-	4.6

Variable Demand Model Alexandra Parade Demo

Route Travel Performance			
Performance Measure	**Vehicles:**	**All MCs (Route)**	**Persons**
Travel Speed (Average)	km/h	3.6	3.6
Travel Distance (Average)	m	1403.0	1403.0
Travel Time (Average)	sec	1422.4	1422.4
Desired Speed	km/h	60.0	
Route Delay (Average)	sec	1927.6	1927.6
Route Stop Rate		7.02	7.02
Route Level of Service (LOS)		LOS F	
Speed Efficiency		0.06	
Travel Time Index		0.00	
Congestion Coefficient		10.00	



Alexandra Pde Intersections with Wellington St & Smith St
Route Travel Performance
(7.45 - 8.00 am flow period)

Route Travel Movement Performance

Mov ID	Turn	Mov Class	Trav Dist m	Midbl. Delay sec	Trav Time sec	Aver. Speed km/h	Aver. Delay sec	Prop. Queued	Eff. Stop Rate	Aver. No. of Cycles	Dem. Flow Rate veh/h	Arv. Flow Rate veh/h	Deg. of Satn
Site ID: 2104S Site Name: Wellington St South Int2													
East Approach													
5	T1	All MCs	916.5	0.0	1203.2	2.7	1664.9	1.00	5.30	6.41	1920	3562	2.415
Site ID: 2103S Site Name: Smith St-South Int2													
East Approach													
5	T1	All MCs	486.5	0.0	219.2	8.0	262.7	1.00	1.72	1.91	1780	1582	1.161

Arrival Flows used in performance calculations are adjusted to include any Initial Queued Demand and Upstream Capacity Constraint effects.

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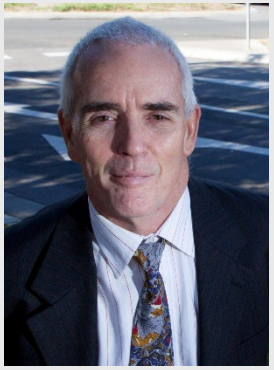

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END OF PRESENTATION

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