Modelling Heavy Vehicles in SIDRA INTERSECTION

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CELEBRATING 20 YEARS

Presentation coverage

1. Movement Classes
2. Vehicle path model (acceleration models)
3. Heavy vehicles in modelling signalised intersections
4. Heavy vehicles in modelling unsignalised intersections
5. Saturation flow and unequal lane use effect of heavy vehicles
6. Related discussion topics

Movement Classes in SIDRA INTERSECTION

Different Movement Classes can be assigned to different lanes and different signal phases

Light Vehicles

Heavy Vehicles

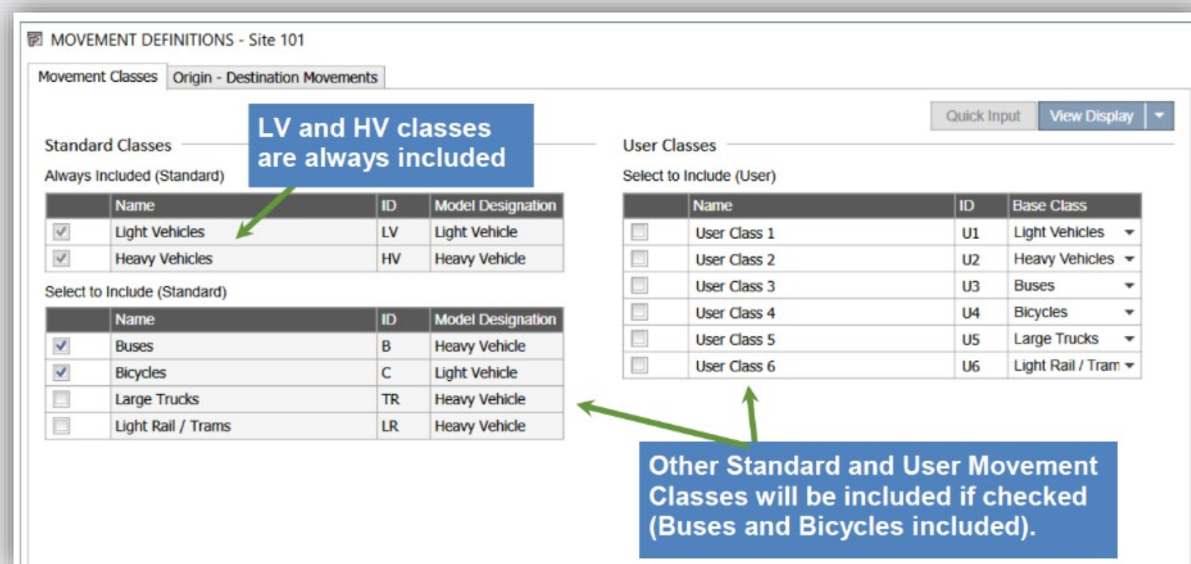
Buses

Bicycles

Large Trucks

Light Rail / Trams

Six User Classes



Model Designation (Light Vehicle / Heavy Vehicle)

Each Movement Class represents an aggregate (composite) vehicle group, and is assigned a Model Designation in relation to the Light Vehicle and Heavy Vehicle characteristics of the Movement Class.

Model Designations for Movement Classes subject to the Include option are:

- Heavy Vehicle for Buses, Large Trucks and Light Rail / Trams
- Light Vehicle for Bicycles.

The Model Designation will affect:

- acceleration and deceleration models
- aggregate HV per cent values for movements, lanes, approaches, intersection, network and route.

Always Included (Standard)

	Name	ID	Model Designation
☑	Light Vehicles	LV	Light Vehicle
☑	Heavy Vehicles	HV	Heavy Vehicle

Select to Include (Standard)

	Name	ID	Model Designation
☑	Buses	B	Heavy Vehicle
☑	Bicycles	C	Light Vehicle
☐	Large Trucks	TR	Heavy Vehicle
☐	Light Rail / Trams	LR	Heavy Vehicle

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Heavy Vehicle Definition

It is necessary to define the compositions of the Standard Light Vehicles and Heavy Vehicles Movement Classes.

- SIDRA INTERSECTION defines a Heavy Vehicle as "any vehicle with more than two axles or with dual tyres on the rear axle" (based on ARR 123, Section 5).

  Thus, buses, trucks, semi-trailers (articulated vehicles), cars towing trailers or caravans, tractors and other slow-moving vehicles are classified as Heavy Vehicles.

  All other vehicles are defined as Light Vehicles (cars, vans, sport utility vehicles, small trucks, motorcycles, bicycles).

- US Highway Capacity Manual defines a Heavy Vehicle as "a vehicle with more than four wheels touching the pavement during normal operation".
- AUSTROADS Glossary 2015 Edition (AP-C87-15) defines a Heavy Vehicle as "a vehicle with a gross vehicle mass or aggregate trailer mass of more than 4.5 tonnes".

Traffic Composition for Light and Heavy Vehicles

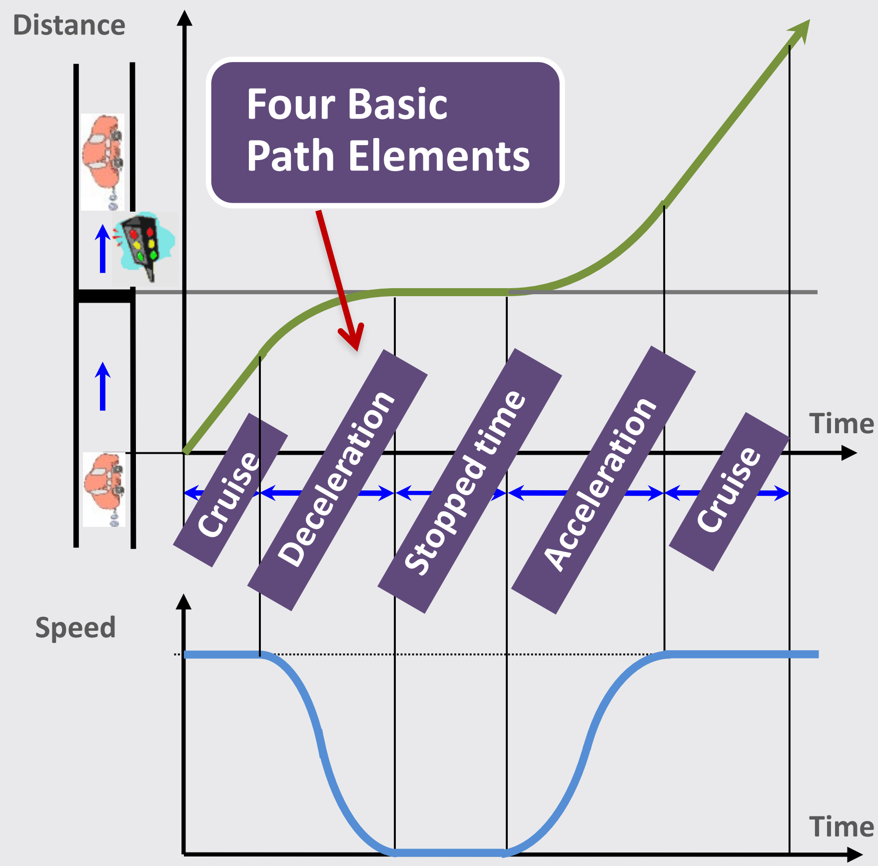
Vehicle Class	Percentage of Vehicle Kilometres	Loaded Mass, M (kg)	Maximum Engine Power (kW)	Power to Weight Ratio (PWR)	Fuel Type (% Diesel)
Light Vehicles					
Small Car	34%	1100	90	81.8	1%
Medium Car	8%	1250	100	80.0	2%
Large Car	25%	1500	130	86.7	2%
SUV	17%	2100	140	66.7	2%
Motorcycle	1%	400	70	175.0	0%
Van	12%	2000	110	55.0	13%
Light Rigid	3%	2700	150	55.6	34%
Combined (Default)	**100%**	**1600**	**120**	**75**	**5%**
Heavy Vehicles					
Light/Medium Rigid	42%	5500	90	16.4	42%
Medium Rigid	10%	10000	120	12.0	90%
Medium / Heavy Truck	10%	16000	170	10.6	100%
Heavy Truck	3%	28000	260	9.3	100%
Heavy Articulated	19%	38000	300	7.9	100%
Bus	15%	8000	170	21.3	80%
Combined (Default)	**100%**	**15000**	**126**	**12.0**	**80%**

User Guide
Table 5.3.1

Vehicle Path Model (Drive Cycles)

Used for the purpose of

- **Emissions** - CO_2, CO, HC, NO_x
- **Fuel Consumption**
- **Operating COST**
- **Geometric Delay**



Articles on Fuel Consumption and Emission Model Calibration:
www.sidrasolutions.com/Resources/Articles

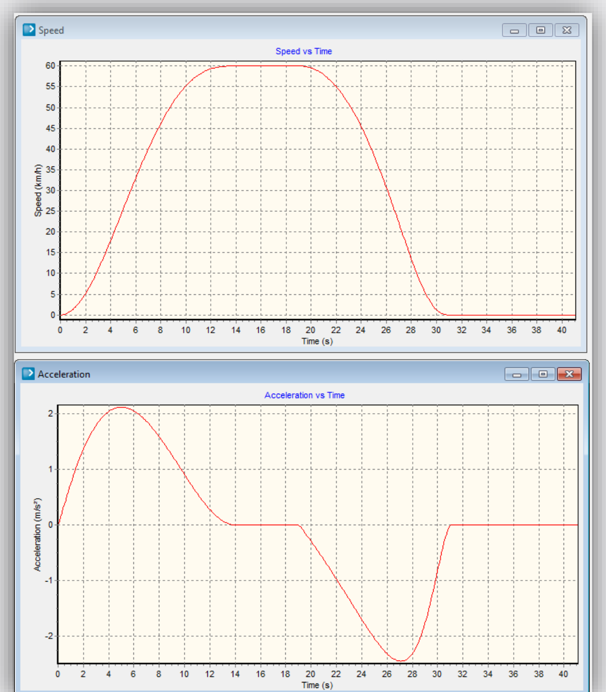
Acceleration – Deceleration Models

Graphs generated by the SIDRA TRIP software

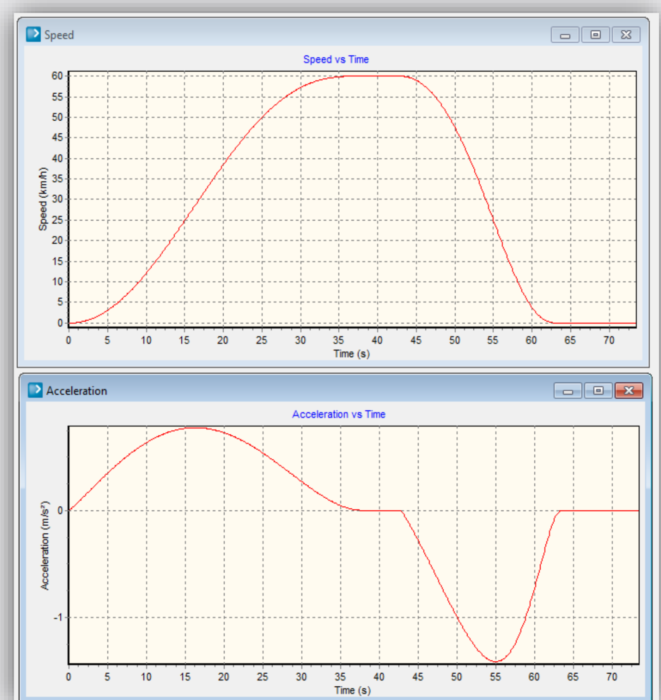
Polynomial acceleration profile model

Constant acceleration model used in traffic engineering for many calculations!

Light Vehicles



Heavy Vehicles



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Default values of vehicle parameters in SIDRA INTERSECTION 8: Mass and Maximum Power

M_v	Average vehicle mass	kg (lb)	Light Vehicles (LV)	1,600 (3,500 lb)
			Heavy Vehicles (HV)	15,000 (33,000 lb)
			Buses (B)	8,000 (18,000 lb)
			Bicycles (C)	90 (200 lb)
			Large Trucks (TR)	38,000 (84,000 lb)
			Light Rail / Trams (LR)	36,000 (80,000 lb)
P_{max}	Maximum Power	kW	Light Vehicles (LV)	120
			Heavy Vehicles (HV)	170
			Buses (B)	170
			Bicycles (C)	0.30
			Large Trucks (TR)	300
			Light Rail / Trams (LR)	360

User Guide Table 5.14.16

Capacity effects of Heavy Vehicles: Signalised Intersections

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Traffic Signals: Saturation Flow Rate and Speed

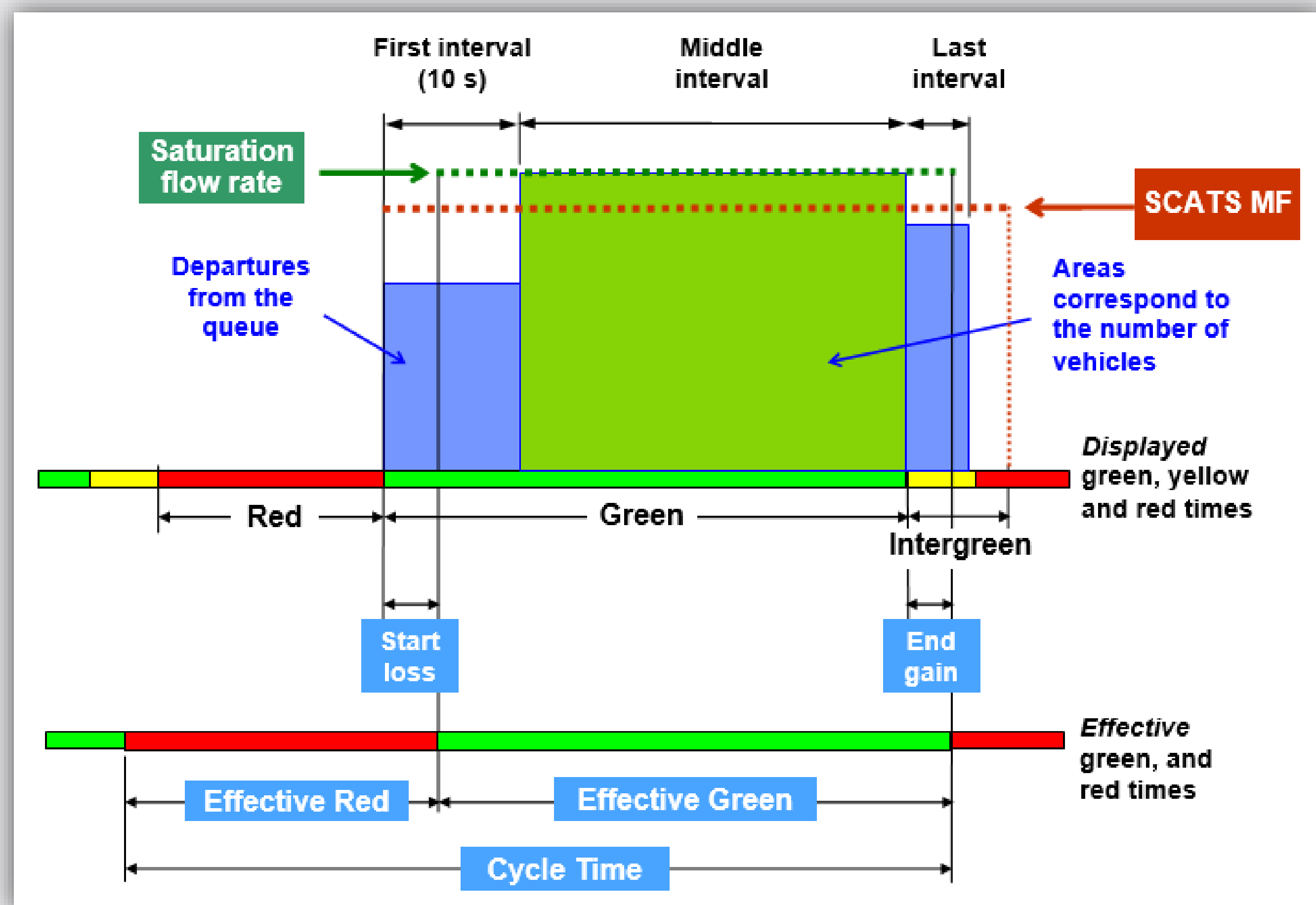
Saturation Flow Rate

The maximum departure (queue discharge) flow rate achieved by vehicles departing from the queue during the green period at traffic signals.

Saturation Speed

The steady speed value associated with queue discharge (saturation) flow rate.

Saturation Flow Survey



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Heavy Vehicles in modelling Saturation Flow Rates at traffic signals

- **Movement Class effects:**
  Passenger Car Equivalents (PCU factors)
- **Turning Vehicle Effects:**
  Turning Vehicle Factors and Turn Radius
  (older options: Normal Turns and Restricted Turns)
- **Combined Movement Class and Turning Vehicle effects:**
  Through Car Equivalents (TCU factors)

PCU: Passenger Car Unit
TCU: Through Car Unit

Movement Class effects on Saturation Flow Rates: Passenger Car Equivalents, e_M

The Passenger Car Equivalent is a factor used to determine the saturation flow rate of a movement at signals to allow for the effect of each movement class in the traffic stream (**passenger cars per vehicle**). This factor is determined using **relative saturation (queue discharge) headway** values of different movement classes under identical road, traffic and control conditions. This is also referred to as **passenger car unit (PCU)**.

For research relevant to the Passenger Car Equivalents used in the SIDRA Standard Model, refer to the following documents:

CUDDON, A.P. (1993). *Lane Saturation Flows at Signalised Intersections in Melbourne*. PhD Thesis. Department of Civil Engineering, Monash University. Melbourne, Australia.

CUDDON, A.P. (1994). Recalibrating SIDRA's saturation flow estimation models. In: Akçelik, R. (Ed.), *Proceedings of the Second International Symposium on Highway Capacity, Sydney, 1994*, ARRB Transport Research Ltd, Vermont South, Australia, Volume 1, pp 203-212.

CUDDON, A.P. and OGDEN, K.W. (1992). The effect of heavy vehicles on saturation flow at signalised intersections. *Proc. 16th ARRB Conf*. 16 (5), pp 1-18.

Movement Class Effects on Saturation Flow Rates

Passenger Car Equivalents, e_M (pcu/veh)

Movement Class	SIDRA Standard Model	SIDRA HCM Model
Light Vehicles (LV)	1.00	1.00
Heavy Vehicles (HV)	1.65	2.00
Buses (B)	1.65	2.00
Bicycles (C)	0.30	0.30
Large Trucks (TR)	2.50	3.00
Light Rail / Trams (LR)	2.00	2.50

User Guide Table 5.14.9

Turning Vehicle Effects on Saturation Flow Rates

- Turning Vehicle Factors
- Turn Radius
- Older options: Normal Turns and Restricted Turns

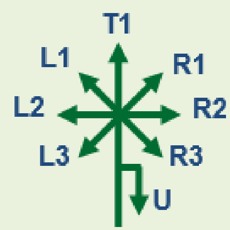
Options for the Turning Vehicle Effect parameter in the Calibration tab of the Vehicle Movement Data dialog are Turning Vehicle Factor and Turn Radius. The Turning Vehicle Effect parameter applies to movements at signals as well as to continuous (uninterrupted) movements at other Site types.

Instead of "Normal" and "Restricted" options used for the Turn Adjustment parameter in old versions (Version 5.1 and older), only the Turning Vehicle Factors (tcu/veh) equivalent to Normal values are provided as input, e_t (tcu/veh).

Turning Vehicle Effects on Saturation Flow Rates: Turning Vehicle Factors, e_t

Turning Vehicle Factors, e_t

OD Movement	Standard Left, New Zealand, NSW Software Setups (Drive Rule = **Left**)	
	LV	HV
L3	1.20	1.20
L2	1.05	1.09
L1	1.02	1.05
T1	1.00	1.00
R1	1.02	1.05
R2	1.05	1.09
R3	1.20	1.20
U	1.40	1.40



User Guide Table 5.11.1

The LV defaults apply to Bicycles, and HV defaults apply to Buses, Large Trucks and Light Rail / Trams.

Turn Radius option for turning vehicle factor

If the Radius option is selected, Turning Vehicle Factor values are calculated as a function of the turn radius using the following equation:

$$e_t = a + b / r_t^c$$

where

e_t = Turning Vehicle Factor,

r_t = turn radius in metres (or feet), and

a, b, c = calibration parameters.

The calibration parameters are a = 1.05, b = 150.0 and c = 3.0. For the US HCM (Customary Units) model, a = 1.05, b = 5297.0 and c = 3.0 are used with r_t in feet.

The values of Turning Vehicle Factors determined from the above equation using the Radius option are the same for all Movement Classes.

Combined Movement Class and Turning Vehicle effects on Saturation Flow Rates: Through Car Equivalents

Passenger Car Equivalents are used together with Turning Vehicle Factors given in the Vehicle Movement Data dialog, Calibration tab to determine ***Through Car Equivalents*** (through car units per vehicle) from:

$$e_{tM} = e_M \, e_t$$

where

e_{tM} = Through Car Equivalent of an OD Movement, Movement Class M (tcu/veh),

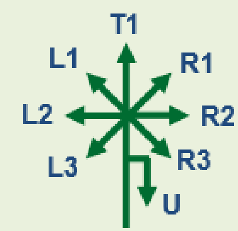
e_M = Passenger Car Equivalent for vehicles of Movement Class M,

e_t = Turning Vehicle Factor for vehicles of an OD Movement, Movement Class M.

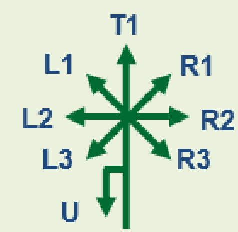
Default values of Through Car Equivalents (combined Movement Class and Turning Vehicle effects)

Through Car Equivalents, e_{tM} (tcu/veh)

Origin-Destination Movement	SIDRA Standard Model (Drive Rule = **Left** or **Right**)		SIDRA HCM Model (Drive Rule = **Right**)	
	LV	HV	LV	HV
L3	1.20	1.98	1.20	2.40
L2	1.05	1.80	1.05	2.10
L1	1.02	1.73	1.02	2.04
T1	1.00	1.65	1.00	2.00
R1	1.02	1.73	1.10	2.20
R2	1.05	1.80	1.18	2.36
R3	1.20	1.98	1.25	2.50
U	1.40	2.31	1.40	2.80



Drive Rule = Left



Drive Rule = Right

User Guide Table 5.14.10

The LV defaults apply to Bicycles, and HV defaults apply to Buses, Large Trucks and Light Rail / Trams.

PCUs, TCUs and Saturation Flow Estimation in veh/h

- The Australian method is to start with tcu/h and make adjustments (including turning vehicle factors) to obtain saturation flow rates in veh/h.
  Arrival flow rates are kept in veh/h.

  Some overseas software require flow rates and saturation flow rates as input in pcu/h (converted for input).

- ARR 123 (1981) recommended the use of volumes and saturation flow rates in Vehicle units NOT PCUs and warned about ERRORS that will result otherwise (Section 5.3.1 and Appendix F of ARR 123).

- SIDRA INTERSECTION 8 User Guide, Section 5.8.1:

> ⇨ An important point about the *turning vehicle factors*, *passenger car equivalents* and *through car equivalents*) (*Sections 5.11.2 and 5.14.2*) is that they are related to queue discharge headways and they should not be used for any purpose other than saturation flow calculations.
>
> ⇨ A common error in other software is the calculation of traffic operating characteristics using arrival flow rates expressed in *passenger car units (pcus)*. The following are some of the errors resulting from the use of this approach. **<<<< Six points are given in the User Guide**

Flow Rate and Saturation Flow Rate in veh/h and tcu/h

Flow Rate, q' (tcu/h) =
Flow Rate, q (veh/h)
x Through Car Equivalent (tcu/veh)

Sat. Flow Rate, s (veh/h) =
Sat. Flow Rate, s' (tcu/h)
/ Through car Equivalent (tcu/veh)

Through car Equivalent (tcu/veh) =
Passenger Car Equiv. x Turning Veh. Factor

Flow Ratio:
y = q (veh/h) / s (veh/h)
= q' (tcu/h) / s' (tcu/h)

Example

Passenger Car Equiv. = 1.65, Turning Veh. Factor = 1.09 (HV Left-turn)
q = 200 veh/h, q' = 200 x 1.65 x 1.09 = 360 tcu/h,
s' = 2000 tcu/h, s = 2000 / (1.65 x 1.09) = 1112 veh/h
Flow Ratio, y = q / s = 200 / 1112 = q' / s' = 360 / 2000 = 0.180

Unsignalised Intersections

Capacity effects of Heavy Vehicles: Unsignalised Intersections

Gap acceptance parameters apply to opposed turns at signals as well (filter turns, slip lanes)

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Movement Class and Turning Vehicle Effects: Follow-up Headway and Critical Gap

- **Gap Acceptance Factor**
  (for vehicles in the entry stream)
- **Opposing Vehicle Factor**
  (for vehicles in the opposing / circulating stream)

The entry stream characteristics and the flow rates of opposing / circulating streams are adjusted for specific Movement Classes (Light Vehicles, Heavy Vehicles, Buses, etc.) using the Gap Acceptance Factor for entry lanes and the Opposing Vehicle Factor for opposing lanes.

These parameters are used for modelling entry streams at roundabouts, filter (permitted) turns at traffic signals, minor streams at two-way sign control as well as all-way stop control.

Default values of the Gap Acceptance Factor and Opposing Vehicle Factor parameters

Gap Acceptance Factor and Opposing Vehicle Factor

Movement Class	Site Type	Standard Left, Standard Right, New Zealand, NSW Software Setups		US HCM Software Setups	
		Gap Accep. Factor	Opp. Vehicle Factor	Gap Accep. Factor	Opp Vehicle Factor
Light Vehicles	All Site types	1.0	1.0	1.0	1.0
Bicycles	All Site types	1.0	0.5	1.0	0.5
Heavy Vehicles, Buses, Trams	Signals	1.5	1.5	2.0	2.0
	Roundabout			2.0	2.0
	TWSC			1.3	1.3
	AWSC			1.5	1.5
Large Trucks	Signals	2.5	2.5	3.0	3.0
	Roundabout			3.0	3.0
	TWSC			2.0	2.0
	AWSC			2.3	2.3

User Guide Table 5.14.10

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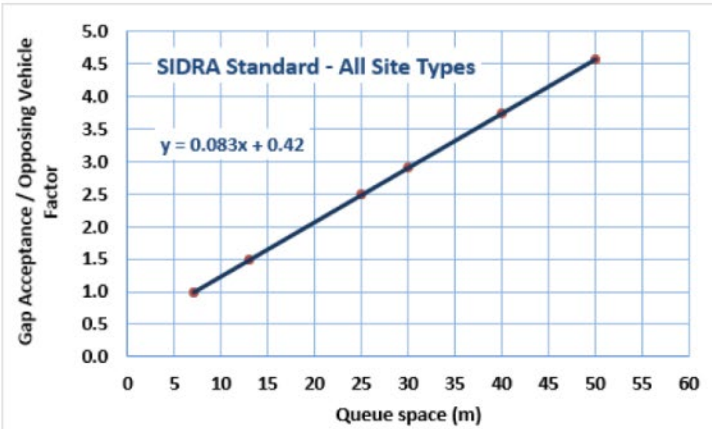
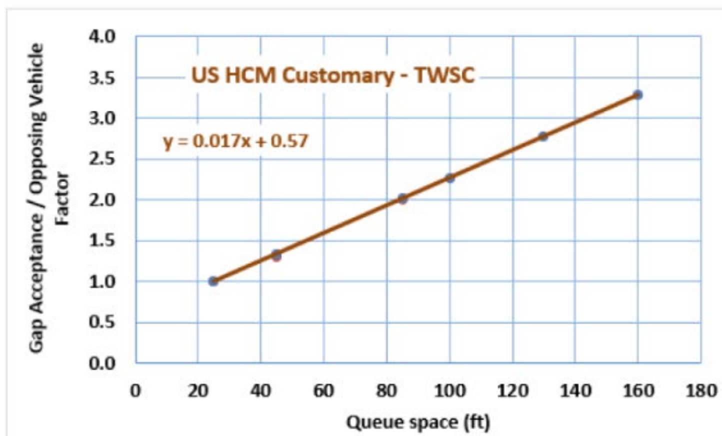
Simple method to specify Gap Acceptance Factor and Opposing Vehicle Factor parameter values for LARGE VEHICLES



For Signals, Roundabout, TWSC and AWSC under the Standard Left, Standard Right, New Zealand, NSW software setups

Specified as a function of the **Queue Space**

For Two-Way Stop Control under the US HCM (Customary) setup



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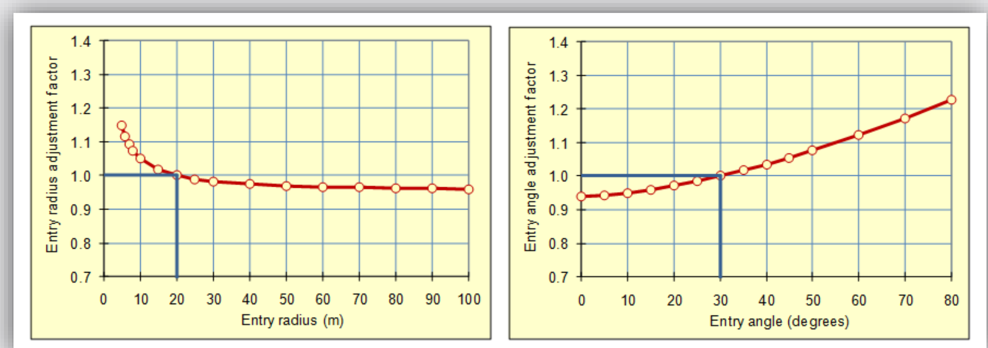
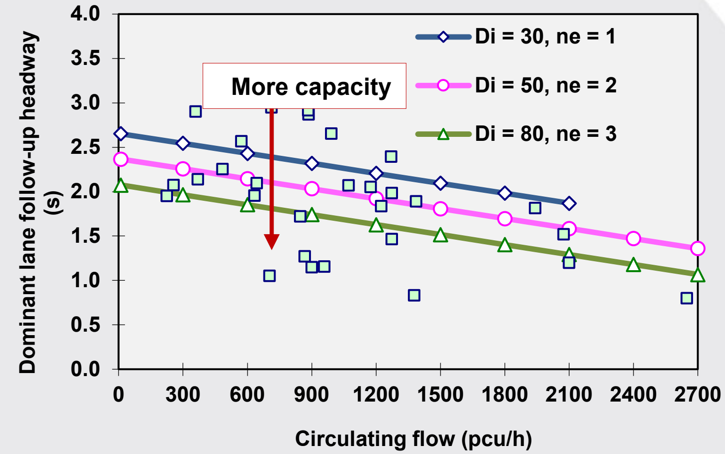
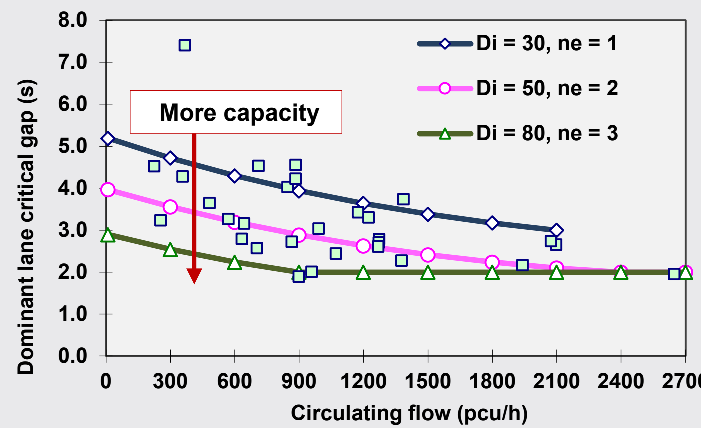
Follow-up headway and critical gap values estimated by the SIDRA Standard roundabout capacity model

- Follow-up headway and critical gap values are
  - sensitive to **roundabout geometry**
  - **decrease with increased circulating flows.**
- **Pedestrian effects** on capacity







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Follow-up headway and critical gap for Two-Way Sign Control (Give Way and Stop)

- **Follow-up Headway** and **Critical Gap** parameters depend on **intersection geometry, control** and **flow composition**

Base* values of Critical Gap (t_c) and Follow-up Headway (t_f)

	SIDRA Standard Model		SIDRA HCM Model	
	t_c	t_f	t_c	t_f
Minor Road Left Turn	5.0	3.0	7.5	3.5
Minor Road Through	6.5	3.5	6.5	4.0
Minor Road Right Turn	7.0	4.0	6.9	3.3
Major Road Turn	4.5	2.5	4.1	2.2

* For a cross intersection with a 4-lane major road and STOP sign control.

SIDRA INTERSECTION incorporates the SIDRA Standard and SIDRA HCM models based on the Austroads Guide to Road Design Part 4A (2017) and the US Highway Capacity Manual (2016) values, respectively.

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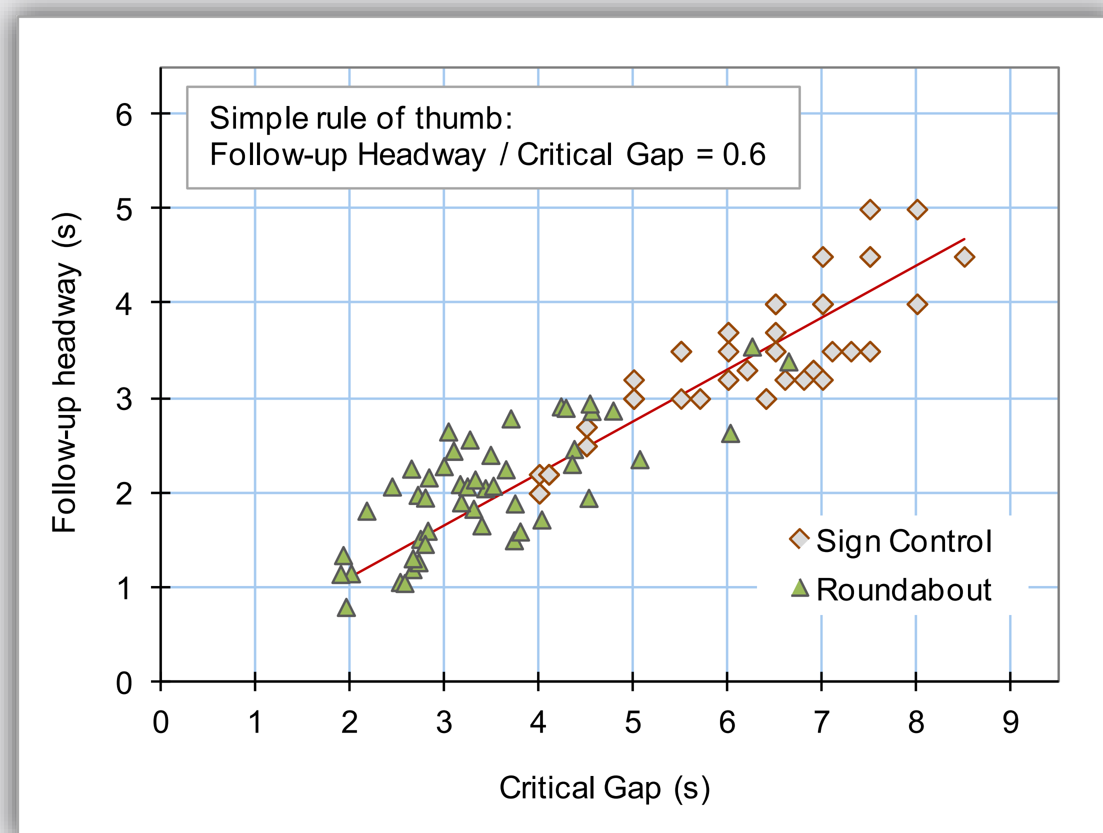
A useful rule of thumb for gap acceptance parameters

Follow-up Headway / Critical Gap ≅ 0.6

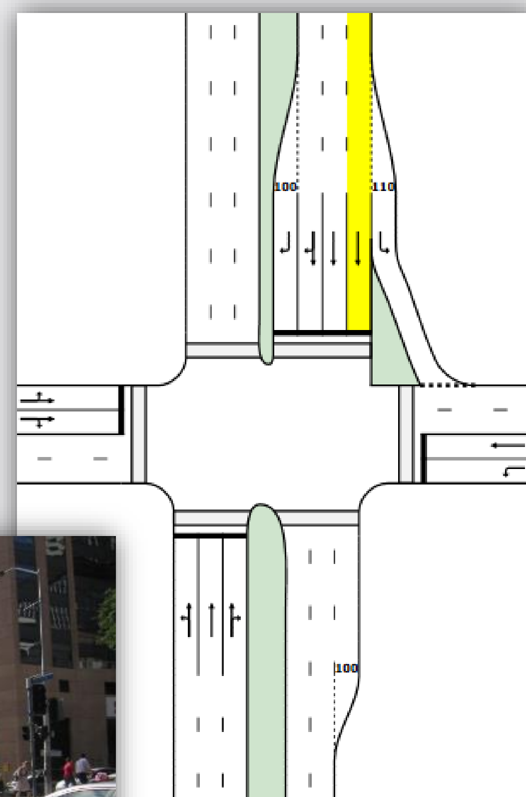


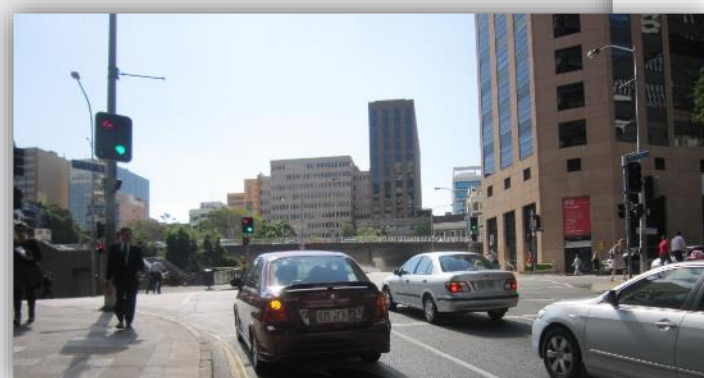
Austroads – SIDRA Standard model data for two-way sign control and the Australian roundabout data

Saturation flows and unequal lane use effect of heavy vehicles

Research needed

Buses Stopping parameter (for signals) only





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Research needs

- Bunched headway distribution model
- Uninterrupted / midblock flows
- Travel time (speed) – flow functions

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Bunched Headway Distribution Model

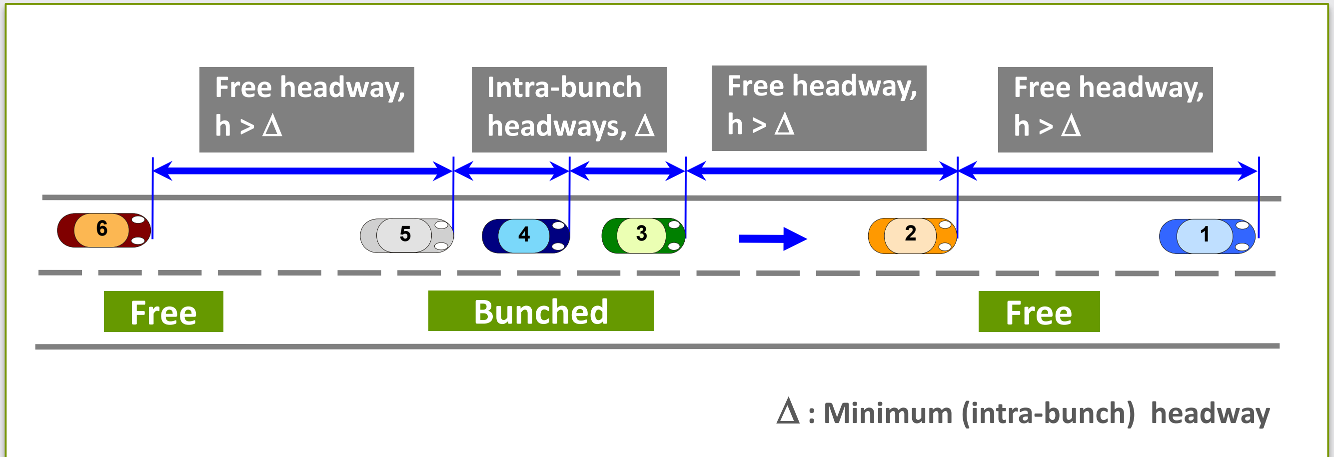
Research needed on the effect of heavy vehicles on bunching in headway distribution models.

Bunched Exponential Headway Distribution Model (Cowan M3) is an important model element for uninterrupted /midblock flows and roundabout circulating flows:

- **Headway distributions**
- **Speed-Flow relationships**

AKÇELIK, R. (2006) Speed - Flow and Bunching Models for Uninterrupted Flows. *Transportation Research Board 5th International Symposium on Highway Capacity and Quality of Service*, Yokohama, Japan

Available on: www.sidrasolutions.com/Resources/Articles



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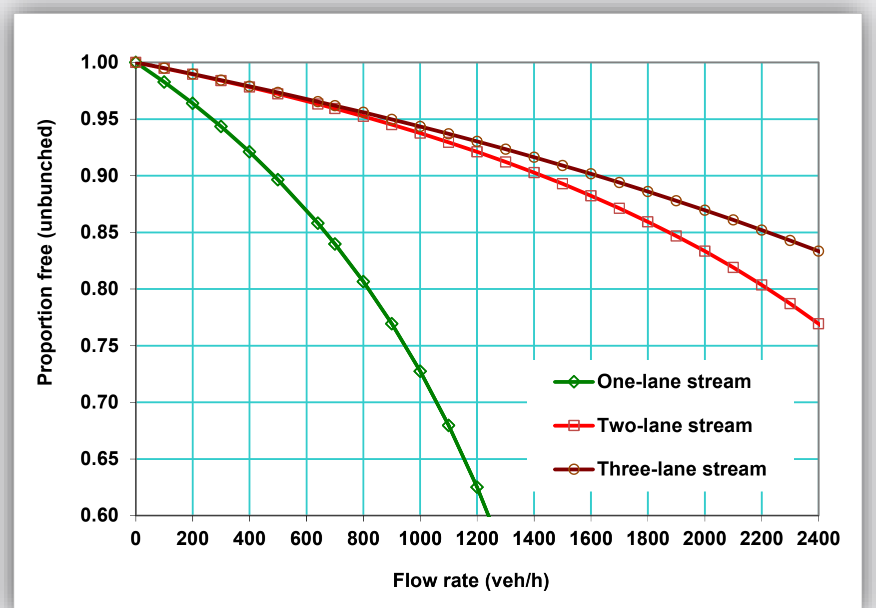
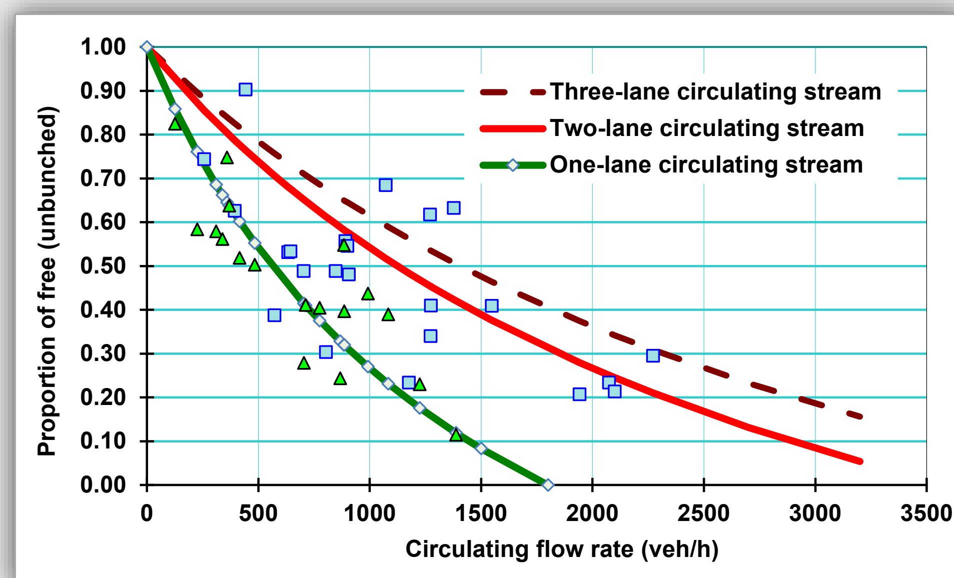
Proportion Bunched

Proportion Bunched for Uninterrupted Flows



Proportion Bunched for Roundabout Circulating Flow



Proportion Bunched = 1 – Proportion Free (shown on the graph)

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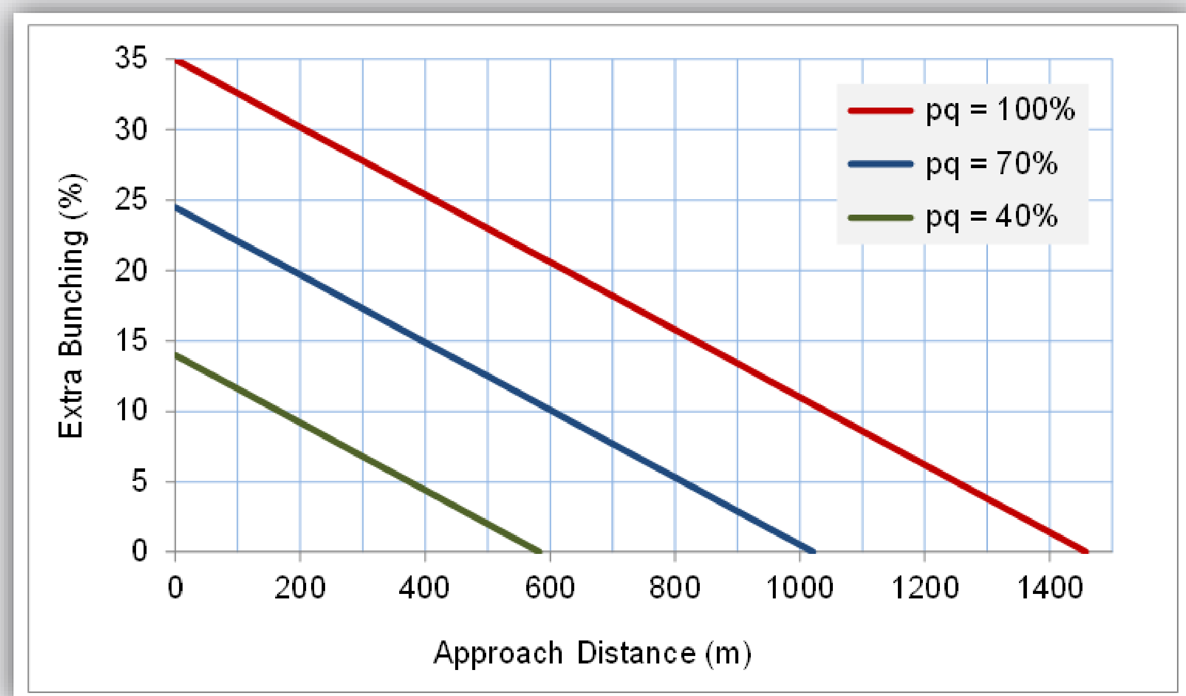
Extra Bunching for Upstream Signal Effects

Research needed on extra bunching due to upstream signals generally, including the effect of heavy vehicles.



Extra Bunching is specified as input or calculated by the program as a function of the **distance to upstream signals** and the **amount of platooning**

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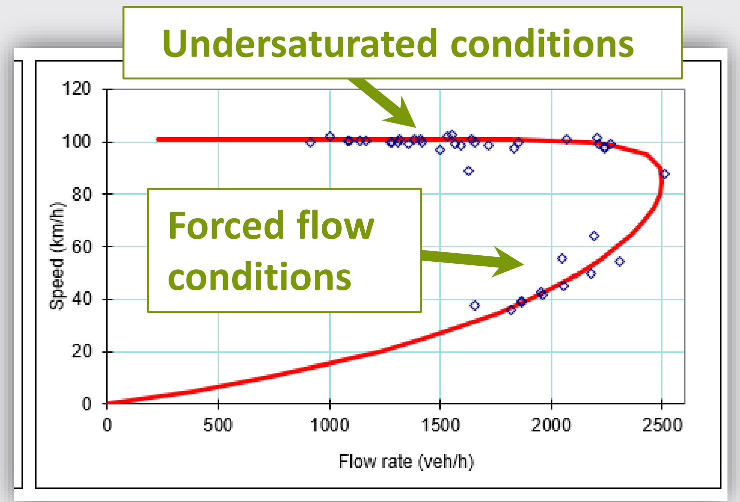
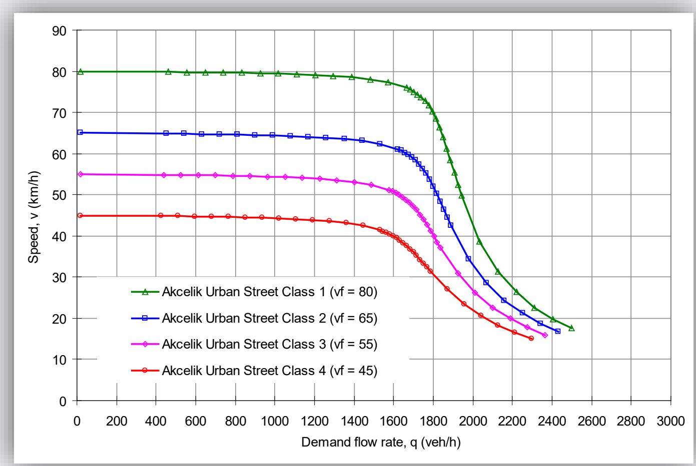
Uninterrupted Flows: Speed – Flow Relationships

Research needed on the effect of heavy vehicles on uninterrupted flow relationships.

Eastern Freeway, Melbourne: Measured and estimated SPEED as a function of FLOW RATE



Travel Speed (HCM 2000 Speed - Flow Models for Urban Streets)



ARRB Research Reports ARR 340 (Signals) and ARR 341 (Freeways)

END OF PRESENTATION