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Gap Acceptance Cycles for Modelling Roundabout Capacity and Performance

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Paper Content and Disclaimer

- Paper Content
  - Introduction
  - Modelling Roundabout Capacity by Gap Acceptance Cycles
  - Back of Queue and Cycle Average Queue
  - A Simple Roundabout Example
  - Concluding Remarks

- The author is the developer of the SIDRA INTERSECTION model used in the study presented in this paper.

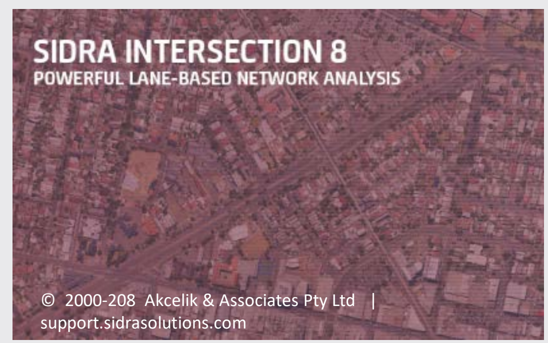
Gap-acceptance theory beyond capacity modelling

Gap-acceptance theory has been used widely for estimation of CAPACITY at roundabouts and sign-controlled (stop and give-way) intersections.

Models for estimating delay, queue length and stop rate for roundabouts and other unsignalised intersections were developed by the author using traffic signal analogy.

This helps with the estimation of fuel consumption and emissions for unsignalised intersections.

The models discussed in this paper have been implemented in the SIDRA INTERSECTION software.



Gap-acceptance theory beyond capacity modelling

This paper will describe the basic method that uses gap acceptance cycles for modelling performance measures with a focus on the modelling of queue length at roundabouts.

The method is applicable to two-way sign control (give-way and stop) as well.

Back of Queue vs Cycle Average Queue is discussed in detail.

A simple single-lane roundabout example is given to explain important aspects of modelling the queue length.

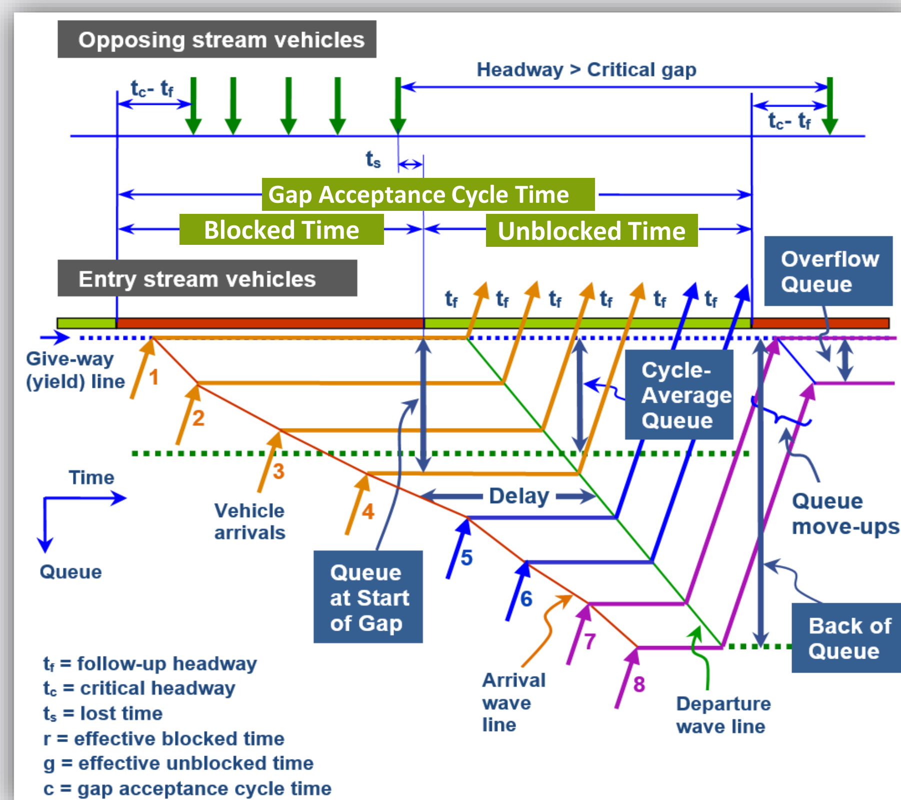
Gap acceptance cycle

This figure depicts modelling of gap acceptance cycles and its application to the modelling of capacity and performance at unsignalised intersections.

A gap acceptance cycle consists of

- **blocked period**
  (vehicles waiting due to lack of an acceptable gap) and
- **unblocked period**
  (vehicles departing when an acceptable gap occurs).

This is similar to a signal cycle that consists of a red period and a green period.



Gap acceptance capacity

$Q = s \times u$

$s = 3600 / t_f$

where

Q = capacity (veh/h)

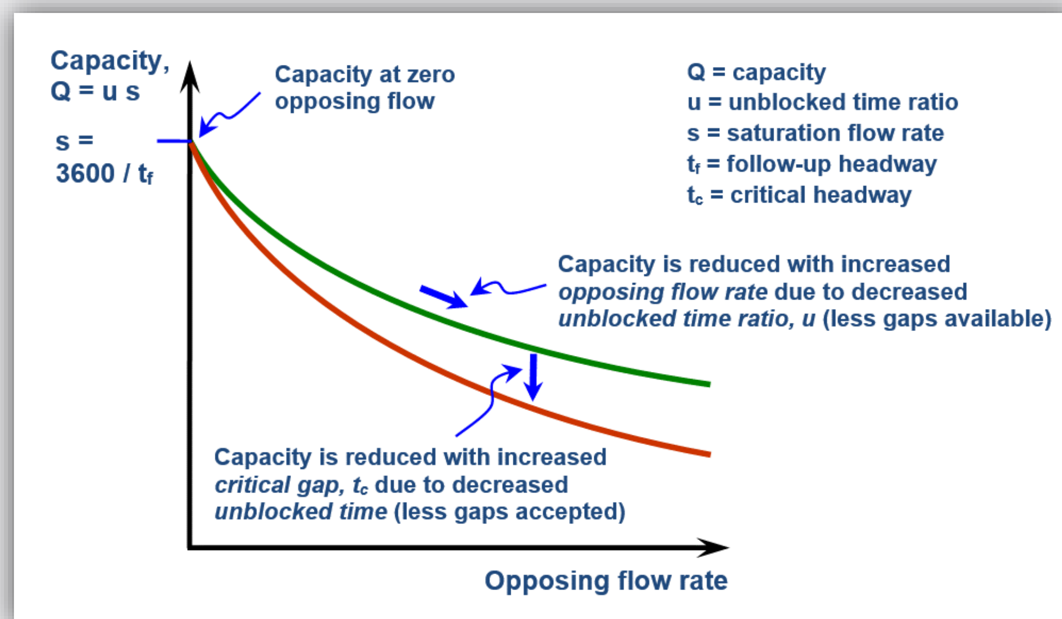
u = unblocked time ratio

(the proportion of time when the vehicles can depart from the queue)

s = saturation flow rate (veh/h)

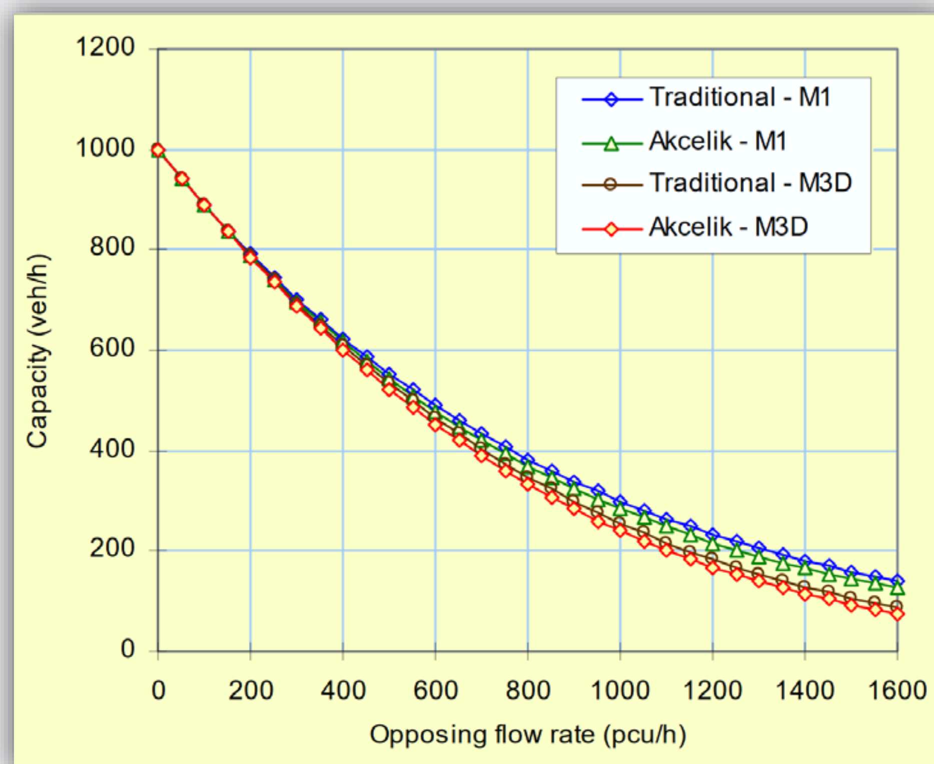
t_f = follow-up headway (seconds)

(saturation headway)



Comparison of gap acceptance capacity models

The increasing difference at high opposing flow rates is due to the bunching assumptions in headway distributions.



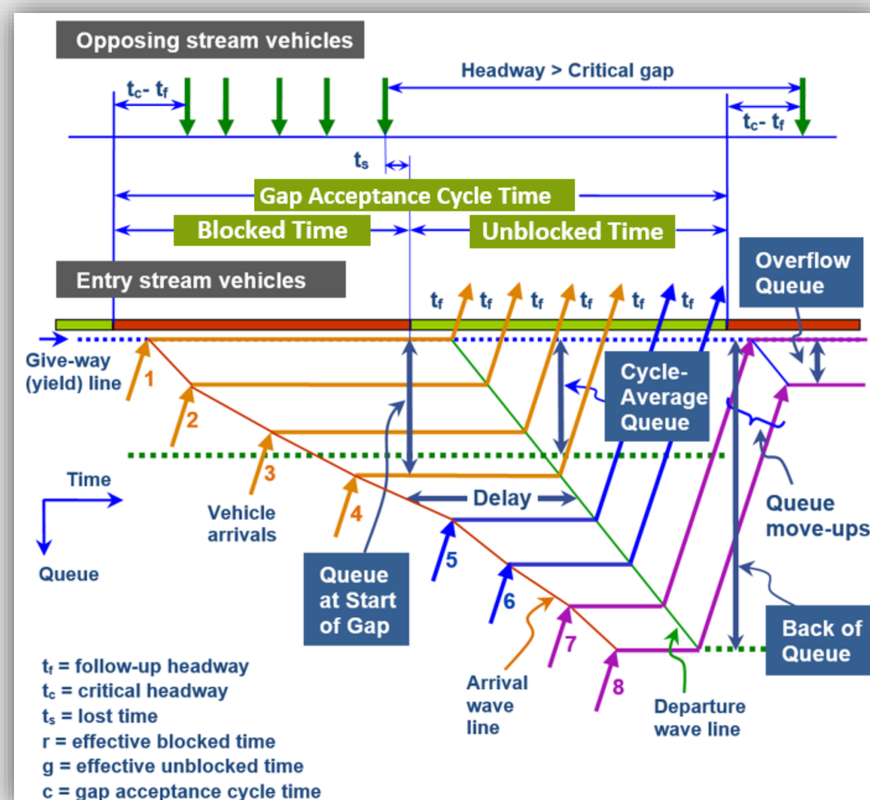
Akçelik, R. (2007). A Review of Gap-Acceptance Capacity Models. 29th Conference of Australian Institutes of Transport Research (CAITR), University of South Australia, Adelaide, Australia.

Back of Queue and Cycle-Average Queue

Back of queue is used commonly for modelling signalised intersection performance.

General literature, various guidelines and traffic theory text books present only the cycle-average queue based on traditional gap acceptance and queuing theory models for unsignalised intersections.

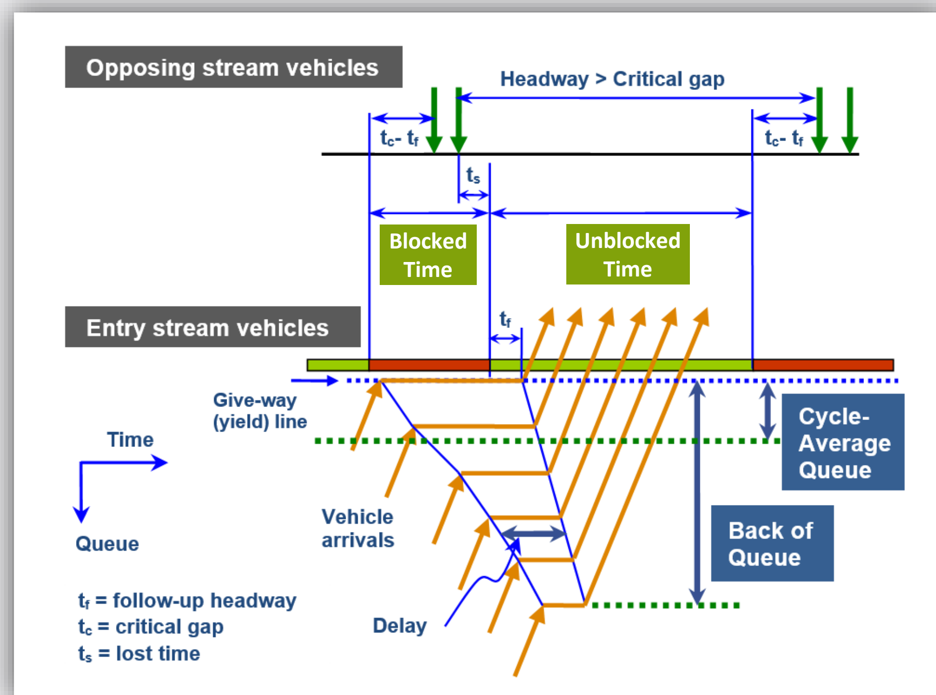
This discrepancy continues to exist in the signalised and unsignalised intersection chapters of US Highway Capacity Manual Edition 6.



Back of Queue for design of appropriate queuing space

Back of queue is a more useful performance measure since it is relevant to the **design of appropriate queuing space:**

- **short lane design** to avoid queue spillback into adjacent lanes
- modelling **blockage of upstream intersection lanes** (queue spillback).



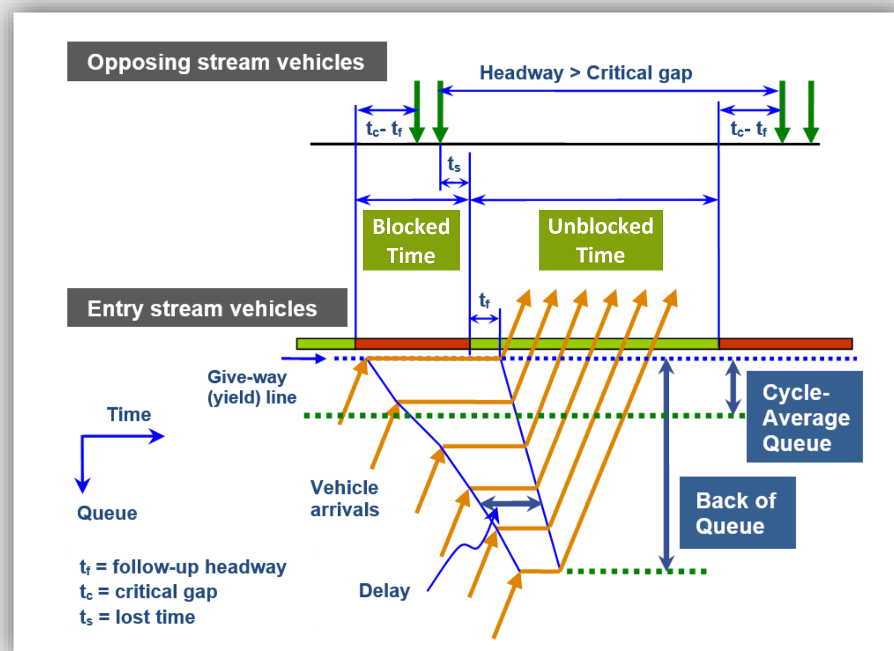
Back of Queue and Delay

Back of queue and delay are not necessarily consistent in terms of magnitude.

- Low delay associated with a long back of queue

  At signalised intersections, this is a result of large green time ratio and a high arrival flow rate.

  At roundabouts, this occurs with large unblocked time ratio (due to low circulating flow rate) and high entry flow rate.



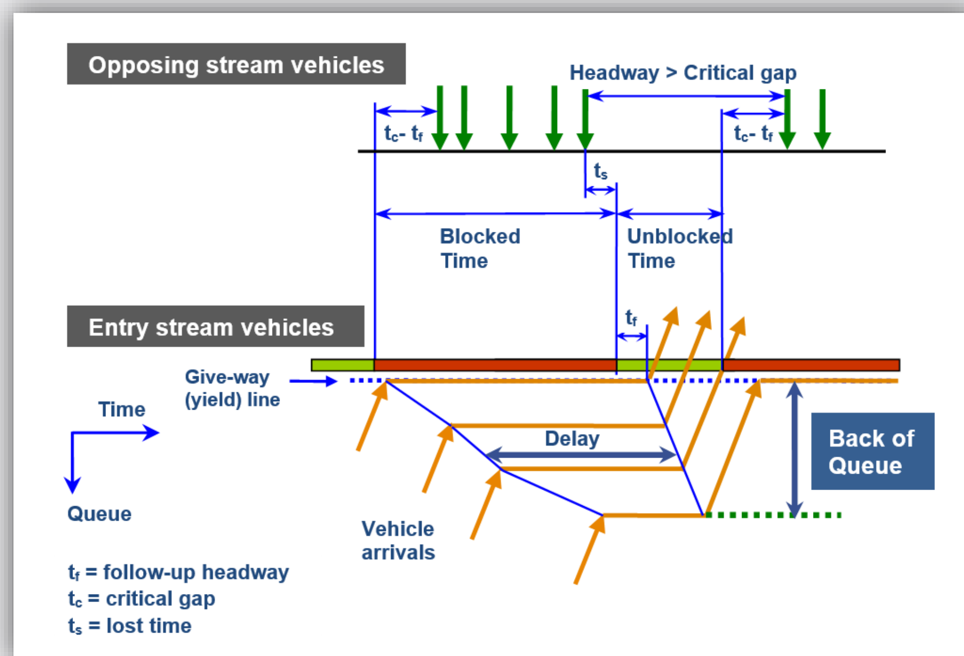
Back of Queue and Delay

Back of queue and delay are not necessarily consistent in terms of magnitude.

- Large delay associated with a short back of queue

  At signalised intersections, this is a result of small green time ratio and a low arrival flow rate.

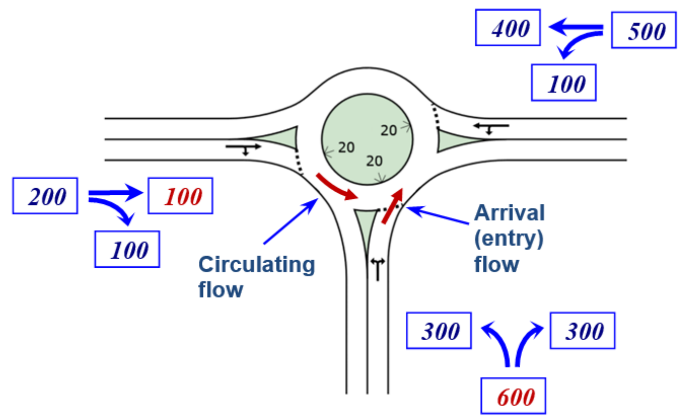
  At roundabouts, this occurs with low unblocked time ratio (due to large circulating flow rate) and low entry flow rate.



A simple roundabout example

Example to demonstrate the relationship between back of queue and cycle-average queue and present the related aspects of modelling using gap acceptance cycles for varying entry and circulating flow rates.

Results were obtained using the SIDRA INTERSECTION standard software setup for driving on the right-hand side of the road.



Inscribed diameter: 36 m
Circulating road width: 8 m
Entry radius: 20 m
Entry angle: 30°
All lane widths: 4 m

No Heavy Vehicles
Peaking parameters:
T = 60 min
T_p = 30 min
PFF = 100 %

Arrival and circulating flow rates tested

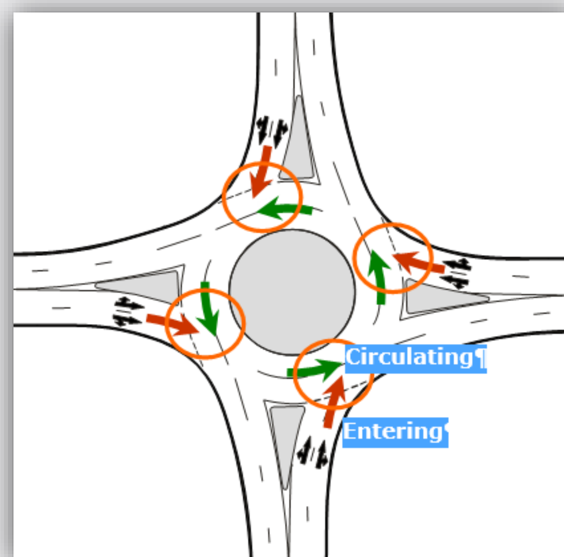
Arrival flow rate, q_a (veh/h)	Circulating flow rate, q_c (veh/h)
300	150 to 1200
600	100 to 900
1000	50 to 500

SIDRA capacity model treating roundabout as an interactive system

The SIDRA Standard roundabout capacity model is based on analysis of a roundabout as a closed system with interactions among roundabout entries

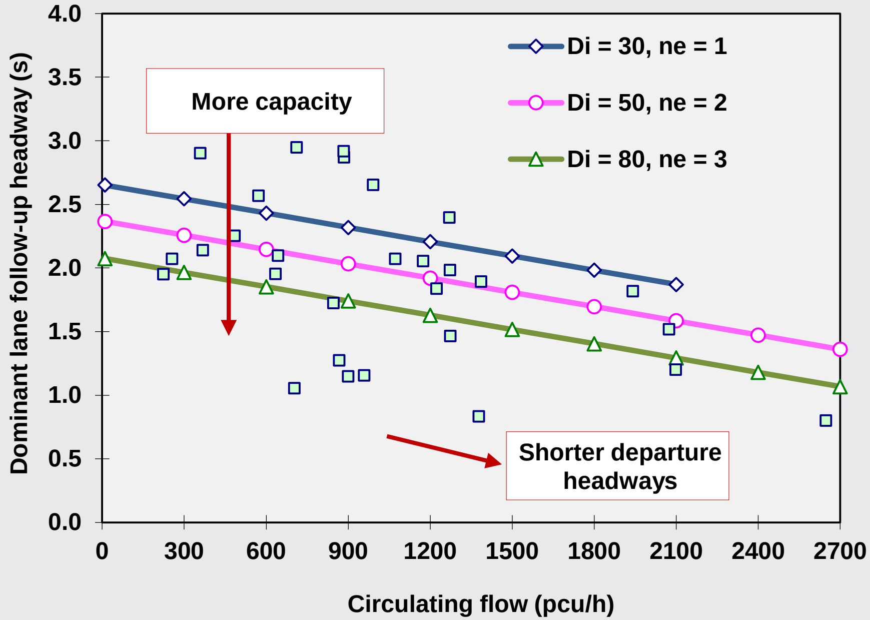
- Capacity constraint
- Bunched headway distribution
  model for the circulating flow
- Lane balance of circulating flow rates
- Unbalanced flow conditions
  (OD pattern and queuing on approach roads)

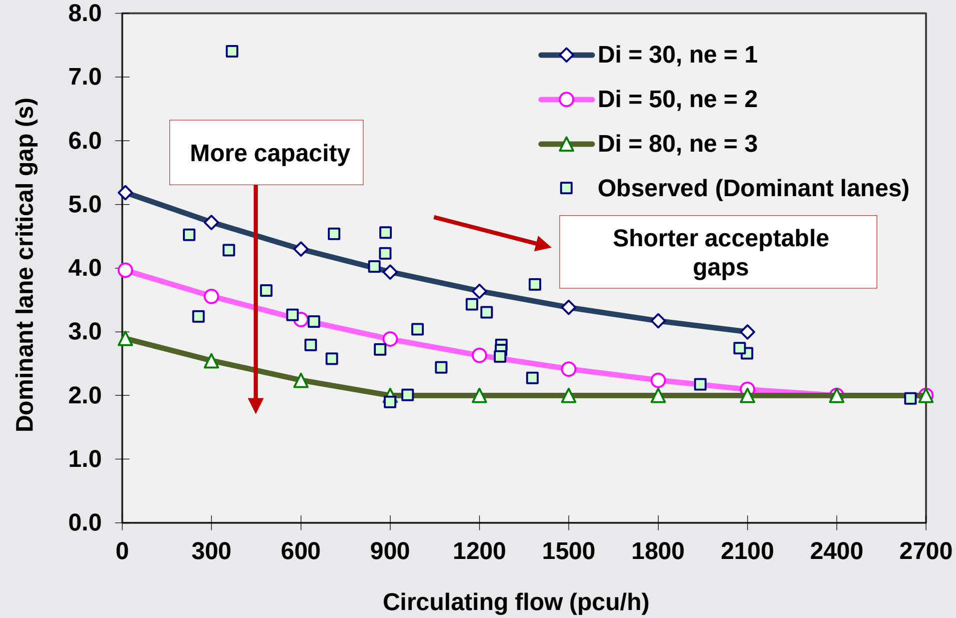
NOT as a series of T intersections …



Driver behavior at roundabouts

In the **SIDRA Standard** model, **critical gap and follow-up headway values are reduced** with increased circulating flow based on the Australian research.

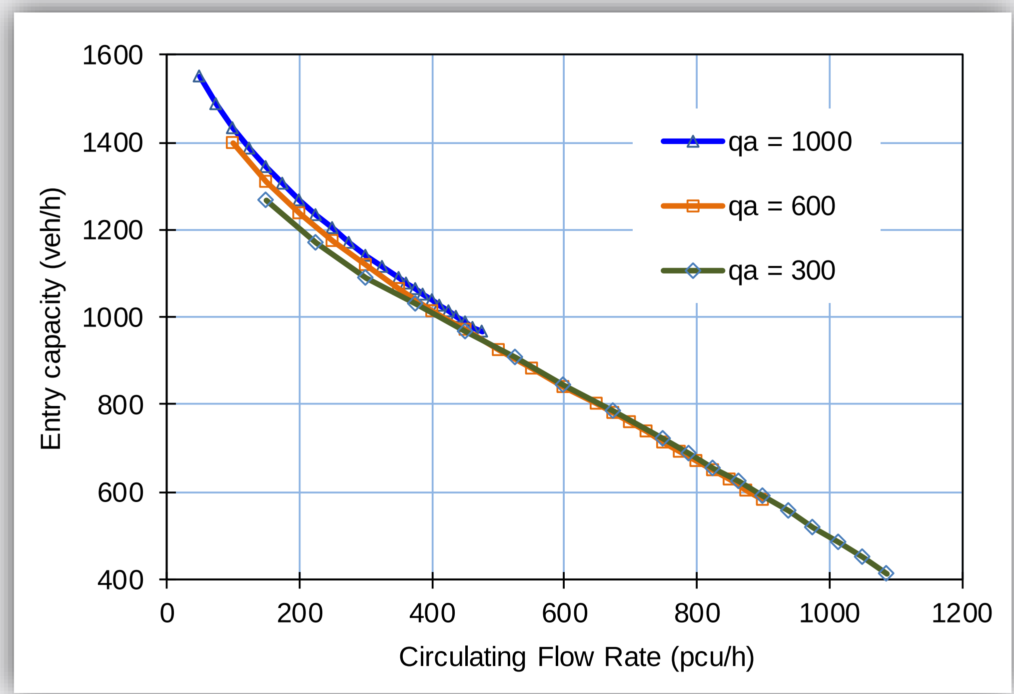




Entry capacity as a function of the circulating flow rate for arrival flow rates of 300, 600 and 1000 veh/h

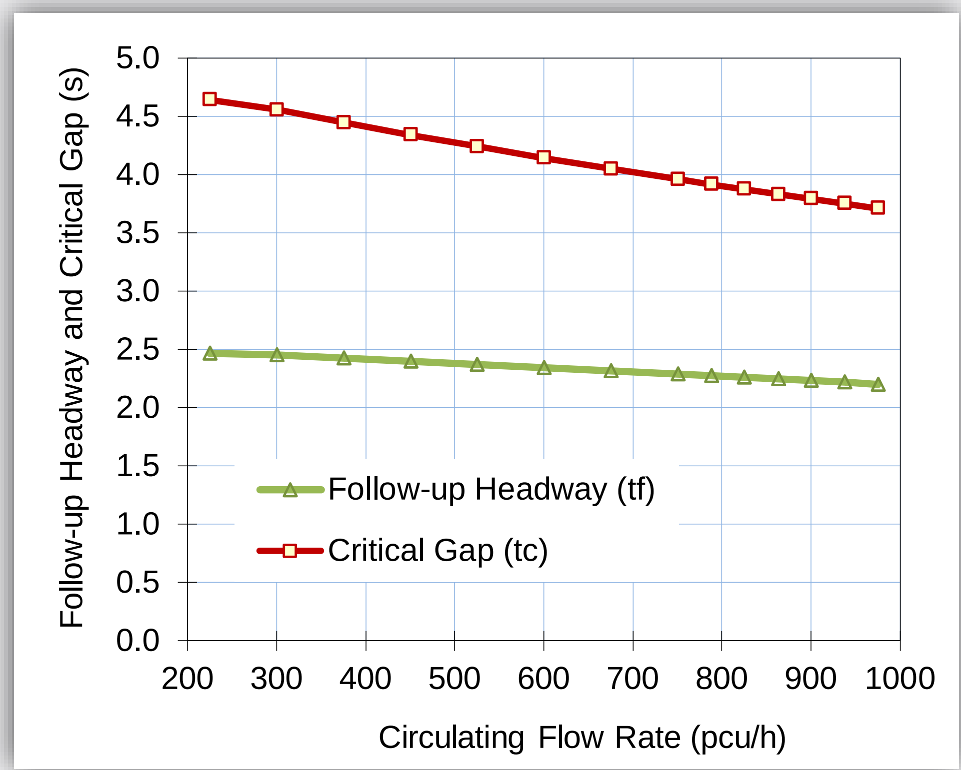
Capacity differences for the three arrival flow rates for low circulating flow rates are due to the effect of the ratio of entry flow rate to the circulating flow rate (higher values of this ratio give higher capacities in the model).

This is an important feature in modelling unbalanced flow conditions.



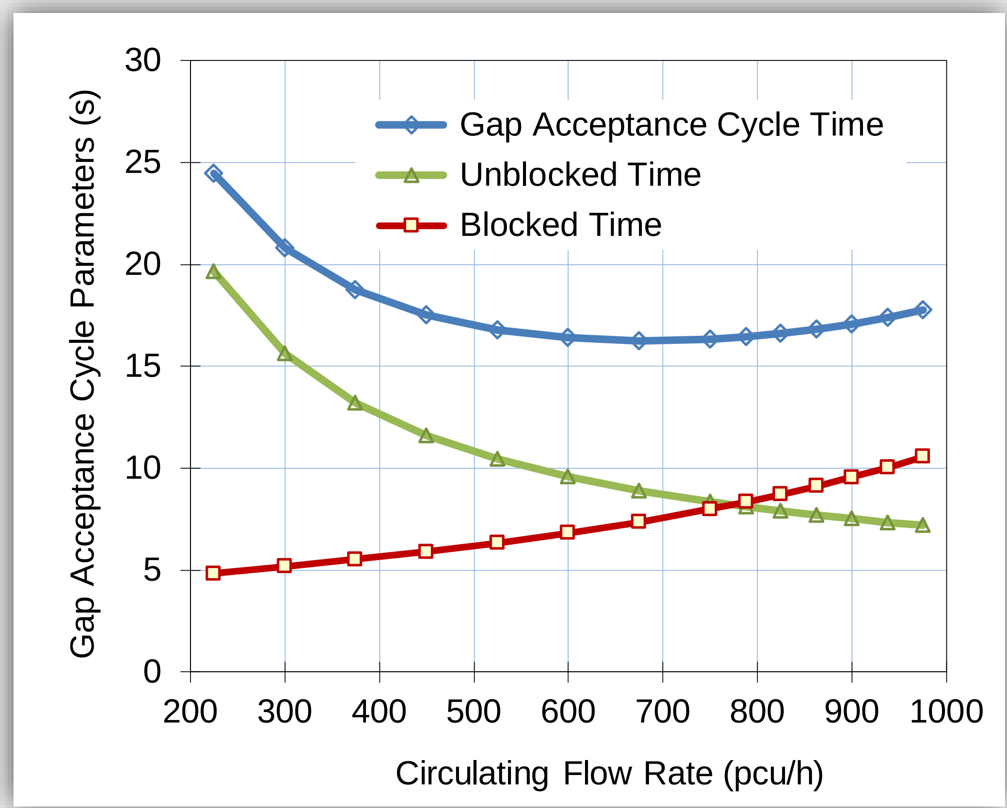
Critical gap and follow-up headway

Critical gap and follow-up headway values reduced with increased circulating flow rates for the single-lane roundabout example



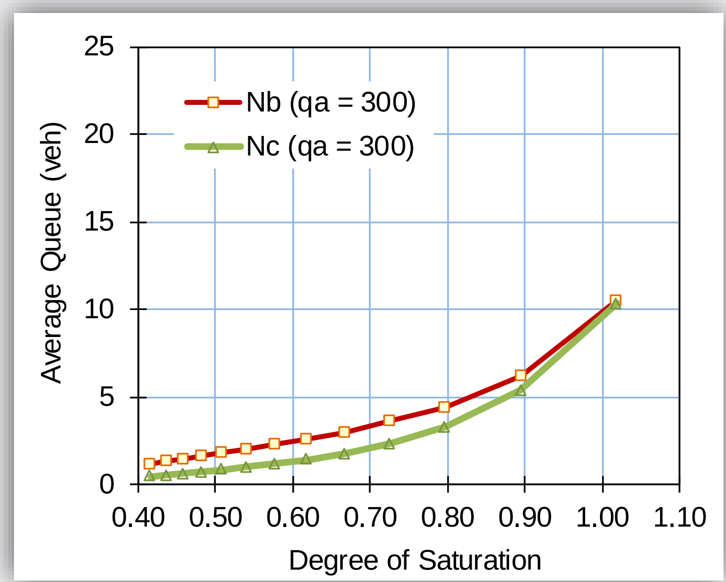
Gap acceptance cycle parameters

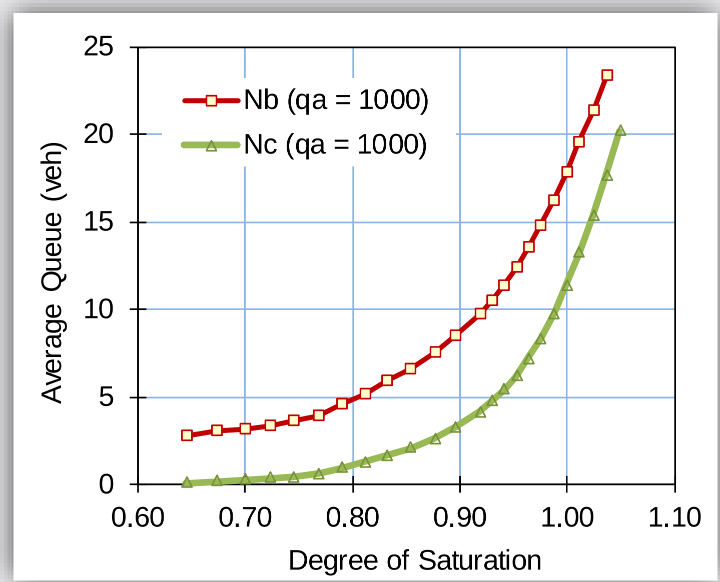
Blocked and unblocked times and the **gap acceptance cycle time** as a function of the circulating flow rate for the case of arrival flow rate of 300 veh/h



Comparison of Back of Queue and Cycle-Average Queue

The difference between the values of average back of queue and cycle-average queue increase with increasing arrival flow rate.



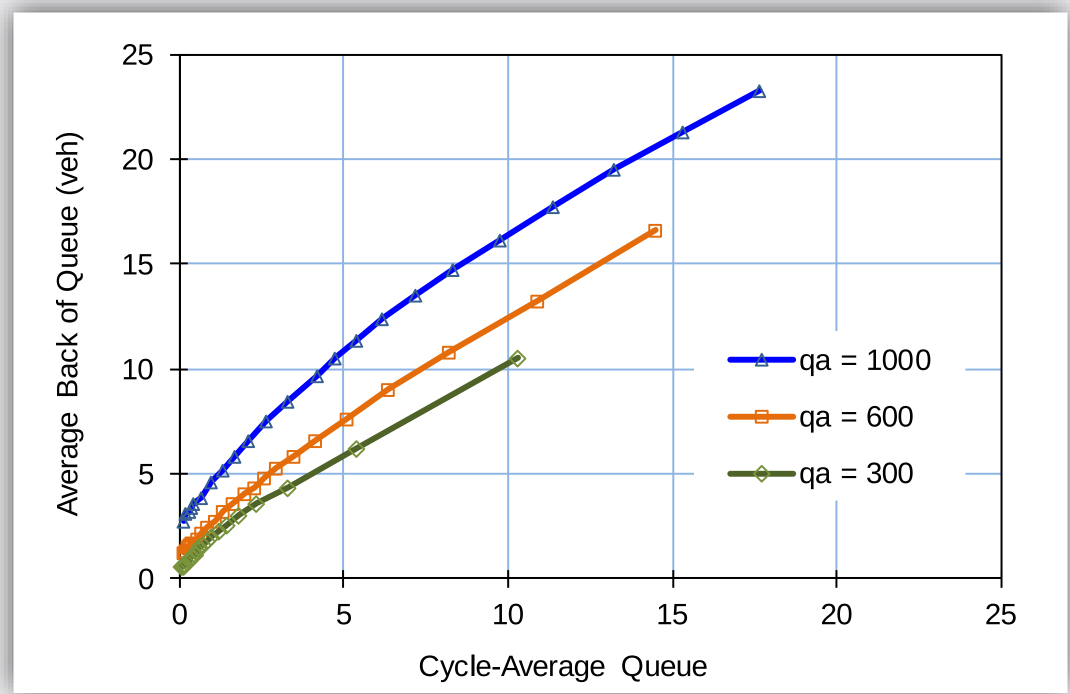


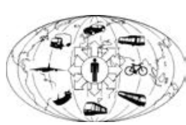
Average Back of Queue and Cycle-Average Queue as a function of the degree of saturation.

Comparison of Back of Queue and Cycle-Average Queue

The **correlation of the average back of queue and cycle-average queue** for arrival flow rates of 300, 600 and 1000 veh/h.

The **difference** between the values of average back of queue and cycle-average queue **increases with increasing arrival flow rate.**





Stopline Delay

Stopline Delay values as a function of circulating flow rate.

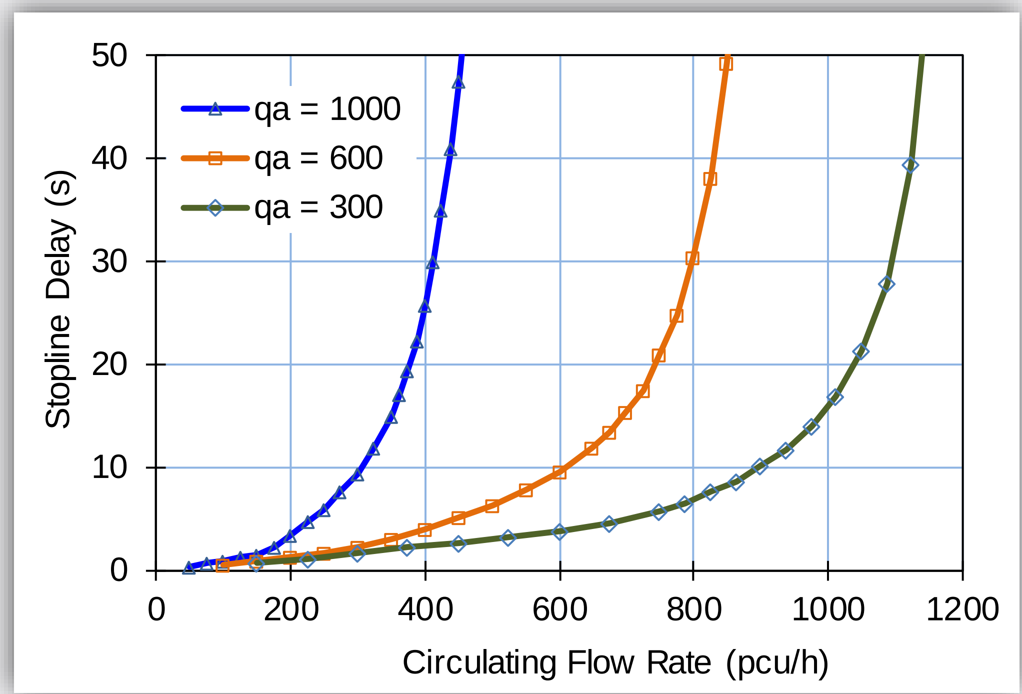
This is used to calculate the **cycle-average queue**:

$$N_c = q \times d$$

where

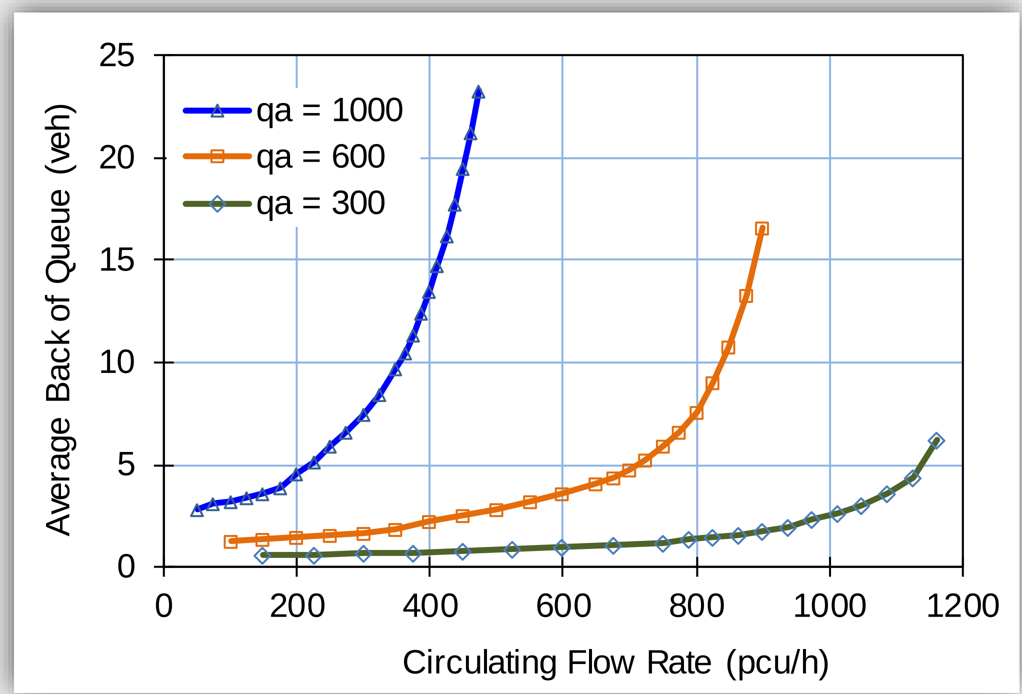
q = arrival flow rate (veh/s)

d = Stopline delay (seconds)



Average Back of Queue

Average Back of Queue values as a function of circulating flow rate



Concluding Remarks

The results given here are from an analytical model developed by the author and are for a simple single-lane roundabout case used for the purpose of this paper.

Further research is recommended by means of

- microsimulation analysis

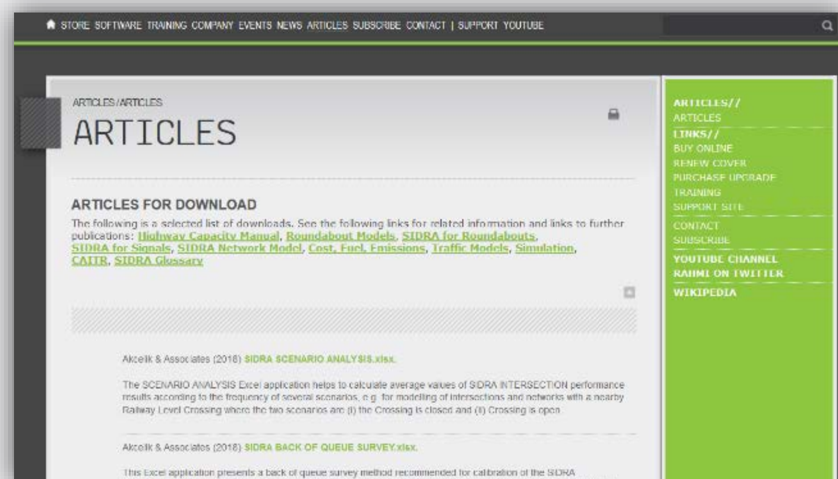
  and

- real-life surveys.

The research should consider complications that arise in real-life situations including the effect of short lanes, variations in various geometric and driver behaviour parameters, slip lanes, effect of upstream signals and pedestrians.

References

Papers and reports based on research by the author and colleagues can be downloaded from
http://www.sidrasolutions.com/Resources/Articles



END OF PRESENTATION

Thank you!

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