Saturation Flow Surveys with Lane Blockage

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CELEBRATING 20 YEARS

Saturation flow rate and saturation speed

Saturation flow rate is a key parameter in the capacity, performance, level of service and signal timing analysis of individual signalised intersections and networks of signalised intersections. It is also a key parameter in determining platoon patterns for signal coordination modelling.

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 queue discharge speed value associated with saturation flow rate.

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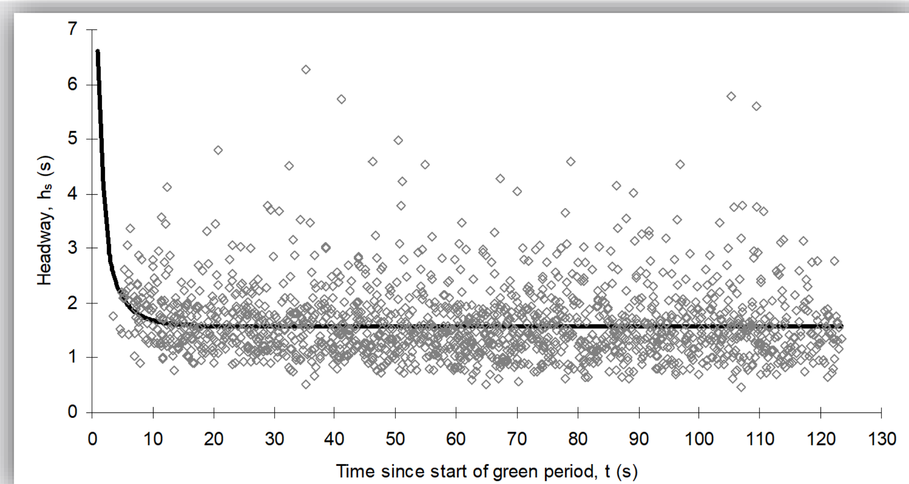
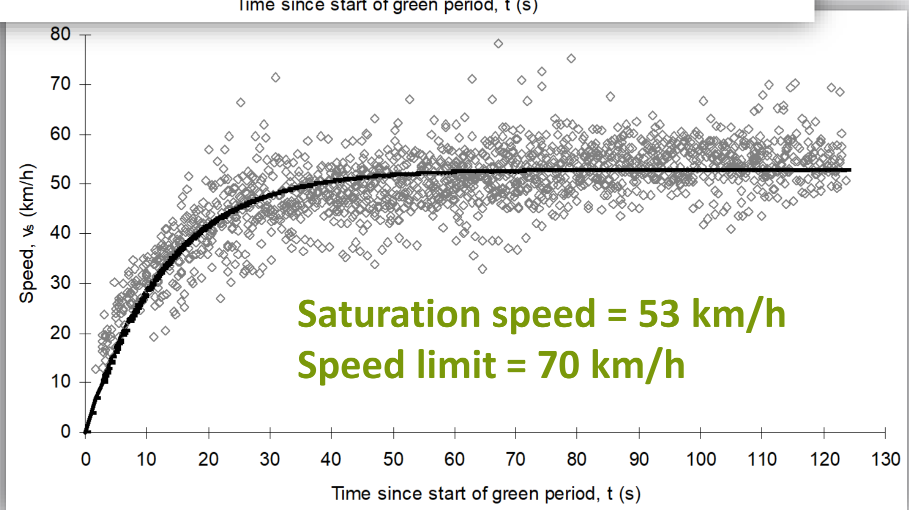
Queue Discharge Headways and Speeds
General Holmes Dve and Bestic St, Sydney (through traffic lane)





ARRB Research Report ARR 340 (Fundamental Relationships for Traffic Flows at Signalised Intersections, 1999)

Recent site visit by Mark Besley, Fraser Johnson and Rahmi Akçelik (20th anniversary)

Saturation flow estimation and survey methods

There are well-established methods for

- the ESTIMATION of saturation flow rates in analytical modelling and
- the SURVEY of real-life saturation flow rates.

These methods are usually based on an implicit assumption that drivers can depart from the queue during the green period without any interruptions by queues forming at downstream intersections.

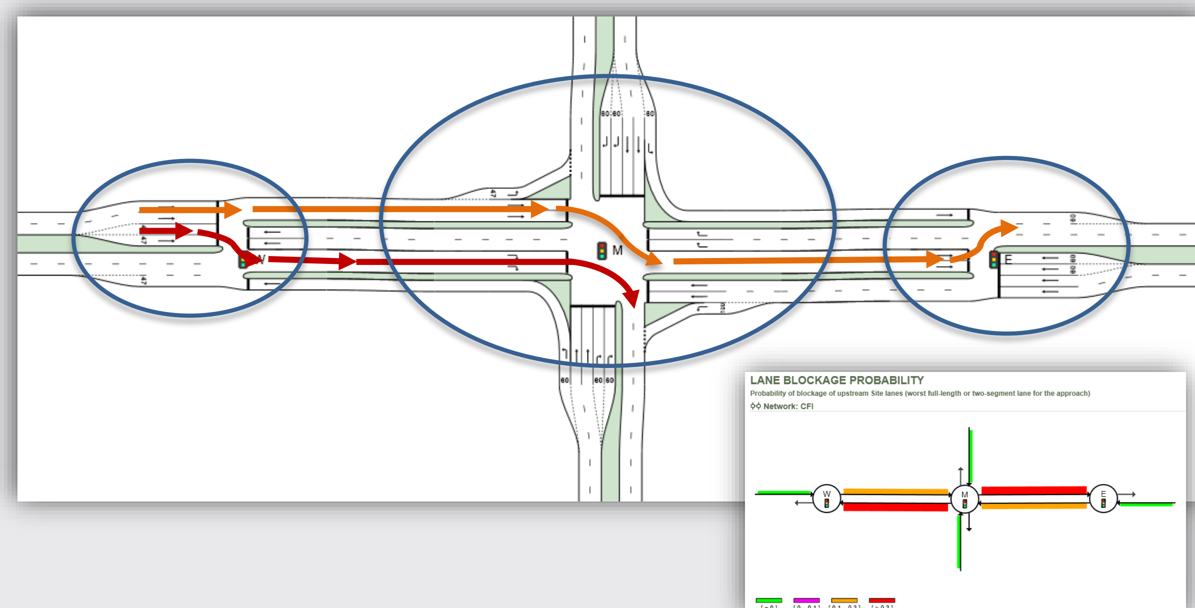
This assumption leads to serious limitations due to the use of such "full saturation flow rates" for closely-spaced intersections when downstream lane queue blockages exist.

Paired (compound) intersections and interchanges

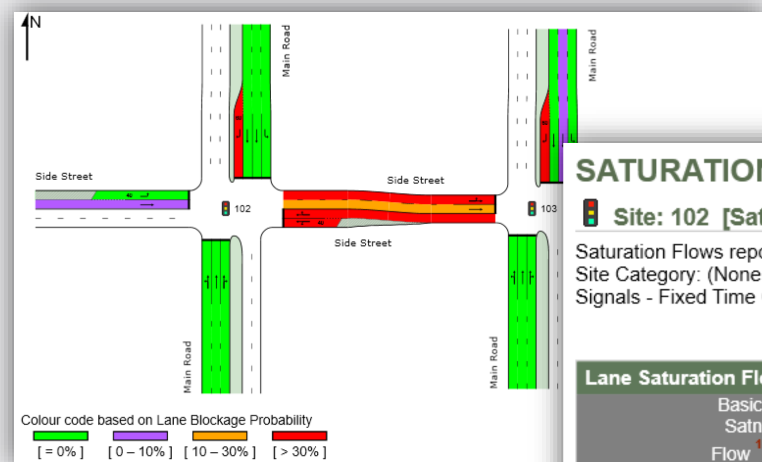
The need to take into account lane blockage effects on saturation flows is particularly important for paired (compound) intersections and interchanges, including alternative (innovative) intersection and interchange designs, under high demand conditions.

Signalised Diamond Interchange,
Doncaster Road - Eastern Freeway, Melbourne

Continuous Flow Intersection (CFI)



Saturation Flows report in SIDRA INTERSECTION 8



SATURATION FLOWS

Site: 102 [Sat Flow Rept 2] **Network: N101 [Network1]**

Saturation Flows report test
Site Category: (None)
Signals - Fixed Time Coordinated Cycle Time = 150 seconds (Network User-Given Cycle Time)

Lane Saturation Flow Rates

	Basic Satn Flow [1]	Factors for Adjusted Basic Satn Flow							Flow Factors		Other Model Elements [4]		Lane Block. [5]		Short Lane [6]	
		[Area Type	Lane Width	Grade	Parking	Buses	Satn Flow Scale	**Satn Flow** [2]]	[MCs & Turns	**Satn Flow** [3]]	[1st Grn	2nd Grn]	[1st Grn	2nd Grn]	[1st Grn	2nd Grn]
	tcu/h							tcu/h		veh/h	veh/h	veh/h	veh/h	veh/h	veh/h	veh/h
South: Main Road																
Lane 1	1950	1.000	1.000	1.000	1.000	1.000	1.000	1950	0.928	1810	1810	-	1810	-	1810	-
Lane 2	1950	1.000	1.000	1.000	1.000	1.000	1.000	1950	0.962	1877	1877	-	1877	-	1877	-
Lane 3	1950	1.000	1.000	1.000	1.000	1.000	1.000	1950	0.940	1833	1833	-	1715	-	1715	-
East: Side Street																
Lane 1	1950	1.000	1.000	1.000	1.000	1.000	1.000	1950	0.941	1836	1836	-	1836	-	1659[8]	-
Lane 2	1950	1.000	1.000	1.000	1.000	1.000	1.000	1950	0.895	1744	2560	-	2560	-	2560	-
North: Main Road																
Lane 1	1950	1.000	1.000	1.000	1.000	1.000	1.000	1950	0.893	1740	1740	-	909	-	909	-
Lane 2	1950	1.000	1.000	1.000	1.000	1.000	1.000	1950	0.986	1923	1923	-	1923	-	1923	-
Lane 3	1950	1.000	1.000	1.000	1.000	1.000	1.000	1950	0.986	1923	1923	-	1923	-	1377[8]	-
Lane 4	1950	1.000	1.000	1.000	1.000	1.000	1.000	1950	0.932	1818	1818	-	1818	-	1270[8]	-
West: Side Street																
Lane 1	1950	1.000	1.000	1.000	1.000	1.000	1.000	1950	0.887	1731	1731	-	1731	-	1731	-
Lane 2	1950	1.000	1.000	1.000	1.000	1.000	1.000	1950	0.978	1908	1908	-	1536	-	1409[9]	-

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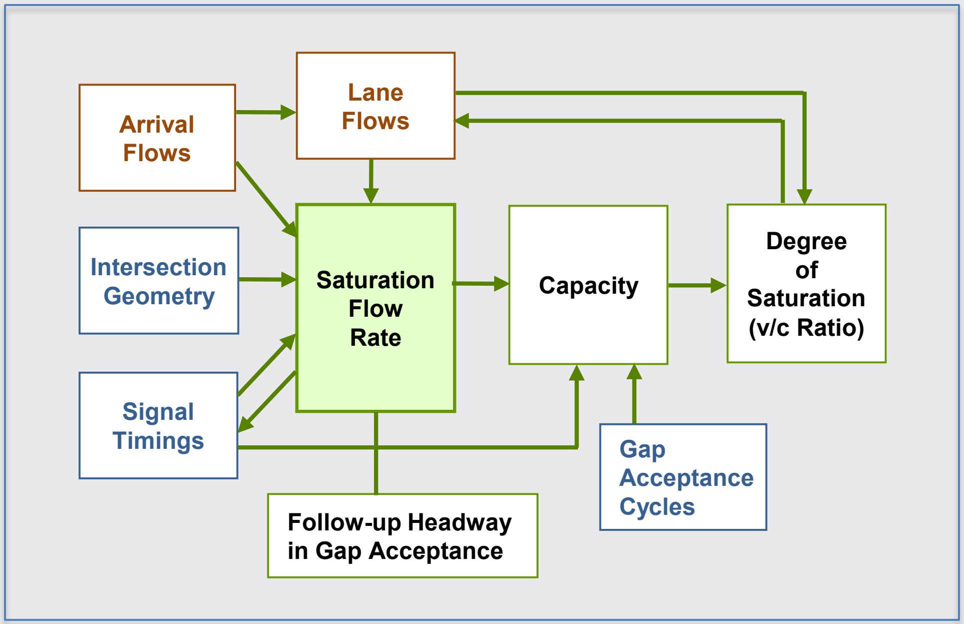
SIDRA INTERSECTION
Lane Flow, Saturation Flow and Capacity estimation (iterative method)



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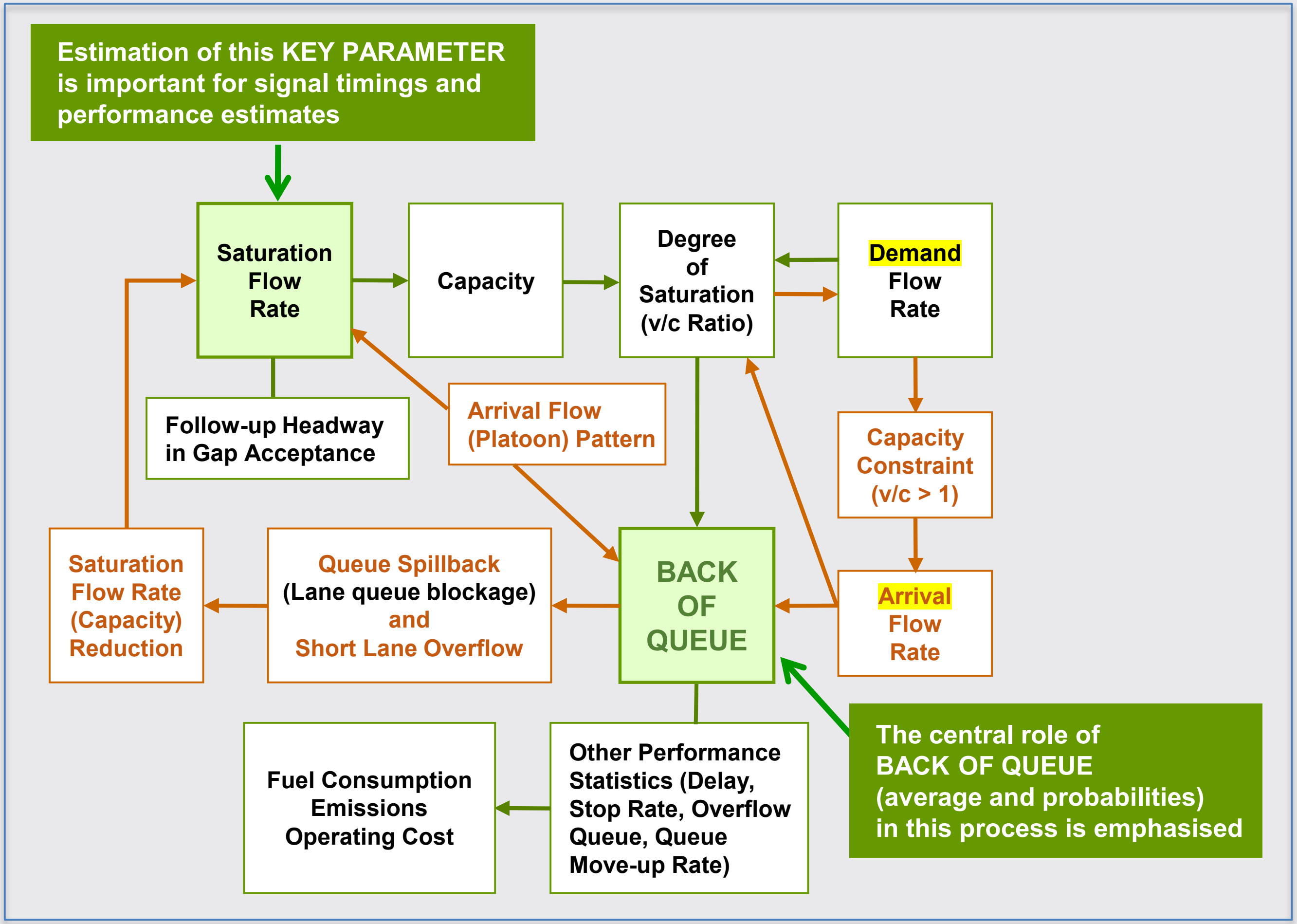
SIDRA INTERSECTION Saturation Flow estimation for networks (iterative method)



Summary of the effects of the main features of the SIDRA INTERSECTION network model on the saturation flow rate and back of queue as key parameters in the iterative capacity and performance estimation process.

The orange-coloured boxes and lines in this flow chart show the unique aspects of the SIDRA INTERSECTION network model.

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Saturation flows reduced due to lane blockage

In analytical modelling of paired (compound) intersections and interchanges in particular, and modelling of signalised intersection networks in general, it is necessary to estimate and calibrate full saturation flow rates (without lane blockage) as well as reduced saturation flow rates resulting from downstream lane queue blockages.

A survey method that can identify both the full and reduced saturation flow rates from the same survey data was developed by the author and used as part of a congestion modelling study in Melbourne, Australia.

YUMLU, C., MORIDPOUR, S. and AKÇELIK, R. (2014) Measuring and Assessing Traffic Congestion: A Case Study. Paper presented at the AITPM 2014 National Conference, Adelaide, Australia, Aug 2014.

Congestion modelling study in Melbourne, Australia: Intersection of Alexandra Parade and Wellington Street

Long queues on the westbound approach of the intersection of Alexandra Parade and Wellington Street lasting for long periods during AM peak.

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Intersection of Alexandra Parade and Wellington Street (wide-median signalised intersection)

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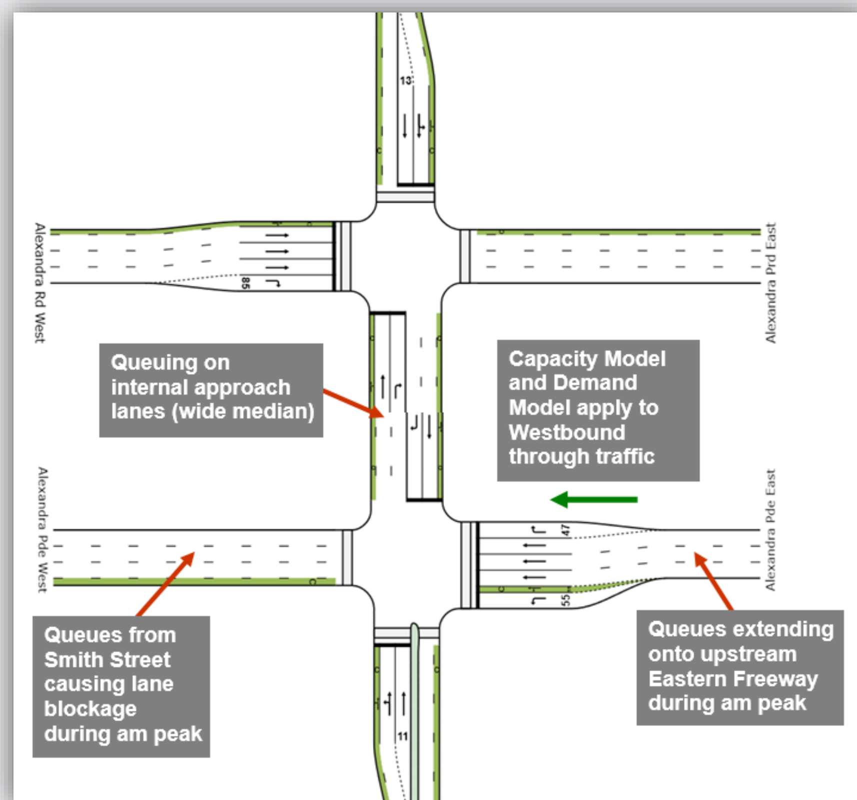
Intersection of Alexandra Parade and Wellington Street

- Westbound lanes blocked frequently by queues extending from the downstream Smith Street intersection: lane blockage values in the range 50 – 60%.
- Low saturation flow rates (50 – 60% capacity loss) as a result.



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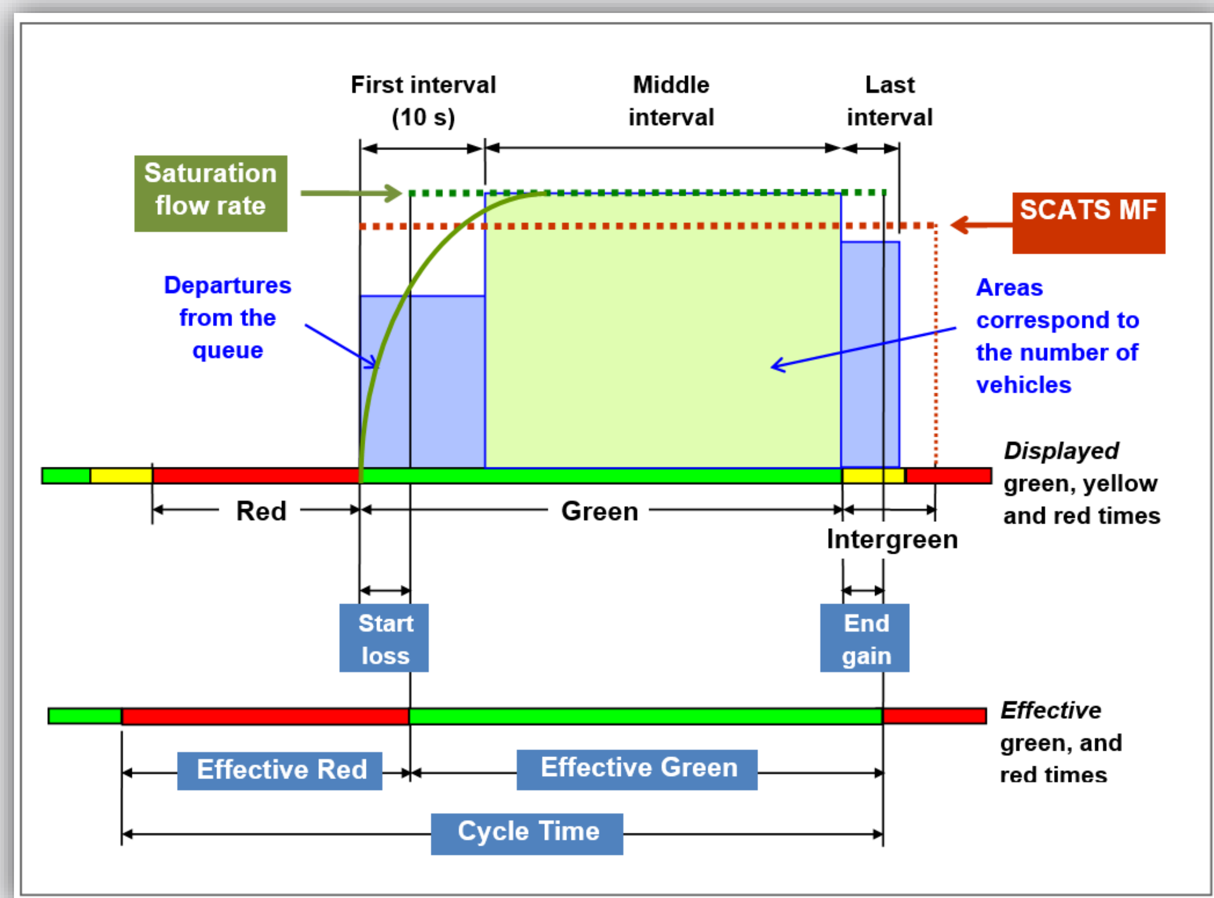
Saturation Flow Surveys: ARR 123 method



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Comparison with the US Highway Capacity Manual (HCM) method

HCM saturation flow survey records the queue departure headways for the first four vehicles and the following vehicles separately.

	HCM Method (n_{vi} = 4)			ARR 123 Method (t_i = 10)		
	s	t_s	t_e	s	t_s	t_e
	(veh/h)	(s)	(s)	(veh/h)	(s)	(s)
Right-turn (isolated) sites	2029	1.7	2.7	2032	1.7	2.7
Through (isolated) sites	2083	2.6	2.6	2083	2.6	2.6
Through (paired int.) sites	1957	1.8	2.8	1958	1.8	2.8
All Through sites	2059	2.4	2.6	2056	2.3	2.6

ARRB Research Report ARR 340, Chapter 12

s: saturation flow rate

t_s: start loss

t_e: end gain

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Extended saturation flow survey method

- ARR 123 saturation flow survey method extended for recording the lane blockage times and taking these into account in saturation flow and lost time calculations.
- Definition of saturation flow under lane blockage effect needs to be clear: This is when the saturation speed is lower than the saturation speed under full saturation flow conditions.

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SATURATION FLOW AND LOST TIME SURVEY for cases with LANE BLOCKAGE

© Akcelik & Associates Pty Ltd 2000-2014

LANE 3 26 February 2014 between 8:52-11:30 am

COUNTS

Cycle Number	Departures from Queue (vehs)			Saturation Time (s)	Green Time (s)	Blockage Time (s)	
	First Interval	Middle Interval (Saturated)	Last Interval			First Interval	First and Middle Intervals
	1	2	3	4	5	7	8
1	3	26	1	92	90	0	29.7
2	4	23	1	74	102	0	26.4
3	2	22	1	51	110	0	26.2
4	3	20	1	72	109	0	29.2
5	5	19	0	78	105	0	26.1
6	3	16	1	90	118	0	46.7
7	3	13	1	113	112	0	43.2
8	3	17	1	116	116	0	42.3
9	4	15	1	90	110	0	36.6
10	3	24	2	91	120	0	22.8

PROCESSING

Cycle Number	Departures from Queue (vehs)			Saturation Time (s)	Green Time (s)	Middle Interval Time (s)	Blockage Time (s)	
	First Interval	Middle Interval (Saturated)	Last Interval				First Interval	Middle Interval
	1	2	3	4	5	6	7	8
1	3	26	1	92	90	82	0	29.7
2	4	23		74	102	64	0	26.4
3	2	22		51	110	41	0	26.2
4	3	20		72	109	62	0	29.2
5	5	19		78	105	68	0	26.1
6	3	16		90	118	80	0	46.7
7	3	13	1	113	112	103	0	43.2
8	3	17	1	116	116	106	0	42.3
9	4	15		90	110	80	0	36.6
10	3	24		91	120	81	0	22.8

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Saturation Flow Surveys with Lane Blockage: Excel application

Cycle Number	Departures from Queue (vehs)			Saturation Time (s)	Green Time (s)	Middle Interval Time (s)	Blockage Time (s)	
	First Interval	Middle Interval (Saturated)	Last Interval				First Interval	Middle Interval
	1	2	3	4	5	6	7	8
1	3	12	1	35	35	25	0	0
2	2	2	0	20	20	10	5	3
3	2	6		24	29	14	7	0
4	3			10	14		0	
5					12			
6	3	2		34	46	24	3	18
7	0	16	1	52	52	42	10	8
8	3	8		44	53	34	0	12
9	3	7	2	34	34	24	0	8
10	2	8	1	27	27	17	0	0
11	2	4		18	33	8	0	0
12	3	8		25	30	15	0	0
13	4	6		22	27	12	0	0
14	3	4		21	34	11	0	0
15	2	11	0	45	45	35	6	10
16	0	10	3	52	52	42	10	15
17	1	15	1	52	52	42	5	6
18	3	10		25	26	15	0	0
19	4	12	2	38	38	28	0	0
20	3	9	1	37	37	27	0	0
21	4	6		23	28	13	0	0
22					10			
23	3	9	1	20	20	10	0	0
24	3	18	0	46	46	36	0	0
25	3	19		45	48	35	0	0
26	2	10	1	32	32	22	0	0
27	4			10	13		0	
28	4	7		24	29	14	0	0
29	2	15	1	50	50	40	0	0
30	3	17	1	52	52	42	0	0
	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Total	74	251	16	917	1024	637	46	80
	n_1	n_2	n_3	n_4	n_5	n_6	n_7	n_8
Samples	28	26	15	28	30	26	28	26
	$A_1=X_1 / n_1$	$A_2=X_2 / n_2$	$A_3=X_3 / n_3$	$A_4=X_4 / n_4$	$A_5=X_5 / n_5$	$A_6=X_6 / n_6$	$A_7=X_7 / n_7$	$A_8=X_8 / n_8$
Average	2.64	9.65	1.07	32.75	34.13	24.50	1.64	3.08

Blockage Time to be recorded as durations of departures from the queue when the **queue discharge speed** is judged to be below the steady **saturation speed** including the conditions when vehicles are not moving.

Full Saturation flow rate (veh/h)	1622	$s = 3600\ A_2 / (A_6 - A_8)$
Reduced Saturation flow rate (veh/h)	1419	$s_r = 3600\ A_2 / A_6$
Full departure flow rate during First Interval (veh/h)	1138	$s_1 = 3600\ A_1 / (10 - A_7)$
Reduced departure flow rate during First Interval (veh/h)	951	$s_{1r} = 3600\ A_1 / 10$
Start loss (s)	3.0	$t_s = 10\ (1 - s_1 / s)$
End gain (s)	2.4	$t_e = A_3 / (s / 3600)$
Average saturated green time (s)	32.8	$g_s = A_4$
Average displayed green time (s)	34.1	$G = A_5$
Effective green time (s)	33.5	$g = G - t_s + t_e$
Proportion of green time blocked	0.1230	[=(X7+X8) / X5]

Recommendations

- Testing of the effectiveness of the survey method by real-life applications. Excel form available.
- Further research related to lane blockage effects on capacity.

Saturation Flow Surveys with Lane Blockage

IMPORTANT REFERENCES

Available for download on www.sidrasolutions.com/Resources/Articles

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END OF PRESENTATION