Unit 3: Transport Study, Traffic Data and Analysis Methods

Module 3-3

Capacity Analysis

Austroads

Traffic Management Training Module

Today's presenter

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Outline of this Module

- Capacity Analysis
- Un-interrupted flow facilities
- Interrupted flow facilities
- Intersection capacity analysis

Capacity Analysis

Capacity Analysis

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Capacity: The maximum flow of vehicles a road can accommodate (HCM, 2010)

Capacity Analysis:

- A quantitative technique for measuring the effectiveness of existing transport facilities in moving traffic and people
- Fundamental to the planning, design and operation of roads and transport services
  - Additional traffic lanes
  - Signal timing adjustments

Capacity Analysis

Application:

- Un-interrupted flow facilities
  - No external factors interrupting traffic flow stream. *E.g. Highways, rural roads*
- Interrupted flow facilities
  - Movement of traffic is interrupted due to intersections, crossings, etc. *E.g. Urban arterials*
- Intersections
  - Where turning movements are allowed. *E.g. signalised and unsignalised*

Un-interrupted Flow Facilities

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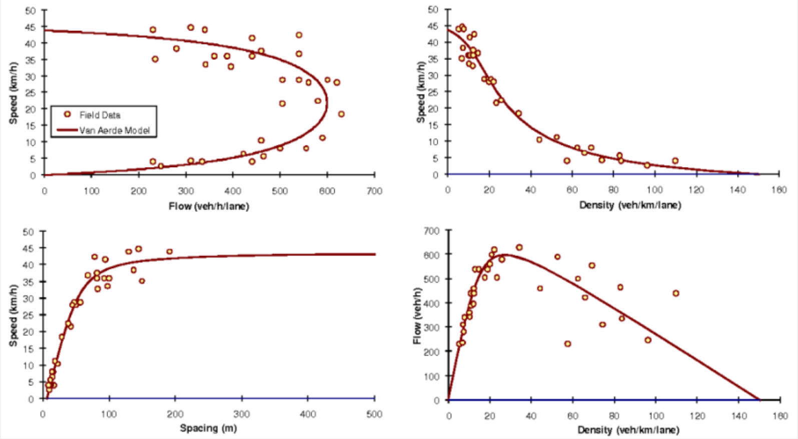
Single-lane Roads

See Section 4.1, Austroads (2020)

Austroads

Peak Flow Capacity *(using Greenshields Model)*

$$C = \frac{v_f \, . k_j}{4}$$



Source: Rakha and Gao (2010)

- Varies between 1000 and 4800 pc/h/ln, mostly within 1500 to 2400 pc/h/ln
- Capacity reduction due to presence of heavy vehicles

$$C = 1800 \, . f_W \, . f_{HV}$$

Two-lane Roads

See Section 4.2, Austroads (2020)

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- Roads with one-lane of travel in each direction
- Generally include rural roads and highways
- Classified into three categories

As per HCM (2016):

- Capacity of a two-lane highway is **1700 pc/h per direction** of travel and is nearly independent of the directional distribution of traffic
- For extended lengths of two-lane highway, the capacity will not exceed **3200 pc/h for both directions** of travel combined.

Multi-lane Roads

See Section 4.3, Austroads (2020)

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- Classified as *undivided* and *divided*

Free-flow speed	Criteria	A	B	C	D	E
100 km/h	Maximum density (pc/km/ln)	7	11	16	22	25
	Average speed (km/h)	100.0	100.0	98.4	91.5	88.0
	Maximum volume to capacity ratio (v/c)	0.32	0.50	0.72	0.92	1.00
	Maximum service flow rate (pc/h/ln)	660	1080	1550	1980	2200
90 km/h	Maximum density (pc/km/ln)	7	11	16	22	26
	Average speed (km/h)	90.0	90.0	89.8	84.7	80.8
	Maximum volume to capacity ratio (v/c)	0.30	0.47	0.68	0.89	1.00
	Maximum service flow rate (pc/h/ln)	600	990	1430	1850	2100
80 km/h	Maximum density (pc/km/ln)	7	11	16	22	27
	Average speed (km/h)	80.0	80.0	80.0	77.6	74.1
	Maximum volume to capacity ratio (v/c)	0.28	0.44	0.64	0.85	1.00
	Maximum service flow rate (pc/h/ln)	550	900	1300	1710	2000
70 km/h	Maximum density (pc/km/ln)	7	11	16	22	28
	Average speed (km/h)	70.0	70.0	70.0	69.6	67.9
	Maximum volume to capacity ratio (v/c)	0.26	0.41	0.59	0.81	1.00
	Maximum service flow rate (pc/h/ln)	290	810	1170	1550	1900

Source: Austroads (2020)

Freeways

See Section 4.4, Austroads (2020)

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- Divided road with two or more lanes per direction with no at grade intersections and full access control

Criteria	LOS				
	A	B	C	D	E
FFS = 120 km/h					
Maximum density (pc/km/ln)	7	11	16	22	28
Minimum speed (km/h)	120.0	120.0	114.6	99.6	85.7
Maximum (v/c)	0.35	0.55	0.77	0.92	1.00
Maximum service flow rate (pc/h/ln)	840	1320	1840	2200	2400
FFS = 110 km/h					
Maximum density (pc/km/ln)	7	11	16	22	28
Minimum speed (km/h)	110.0	110.0	108.5	97.2	83.9
Maximum (v/c)	0.33	0.51	0.74	0.91	1.00
Maximum service flow rate (pc/h/ln)	770	1210	1740	2135	2350
FFS = 100 km/h					
Maximum density (pc/km/ln)	7	11	16	22	28
Minimum speed (km/h)	100.0	100.0	100.0	93.8	82.1
Maximum (v/c)	0.30	0.48	0.70	0.90	1.00
Maximum service flow rate (pc/h/ln)	700	1100	1600	2065	2300
FFS = 90 km/h					
Maximum density (pc/km/ln)	7	11	16	22	28
Minimum speed (km/h)	90.0	90.0	90.0	89.1	80.4
Maximum (v/c)	0.28	0.44	0.64	0.87	1.00
Maximum service flow rate (pc/h/ln)	630	990	1440	1955	2250

Source: Austroads (2020)

As per Vicroads (2013):

At 100 km/h free-flow speed,

- 15% reduction in capacity when traffic comprises 10% HV
- Maximum flow can be maintained through ramp metering

Interrupted Flow Facilities

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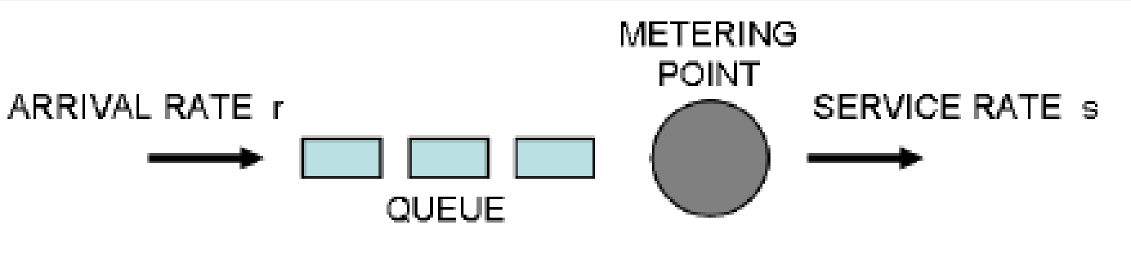
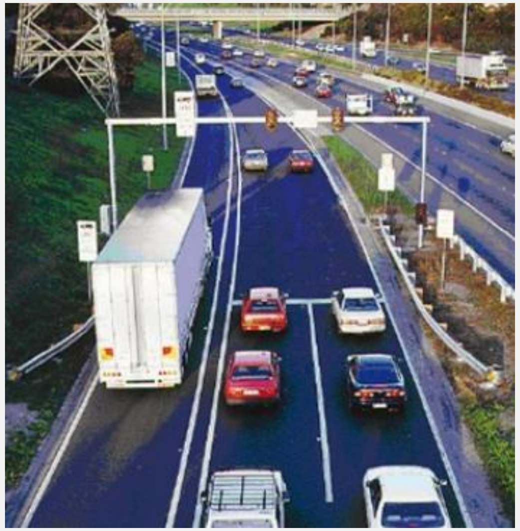
Metered Flow

See Section 5.1, Austroads (2020)

- Metering the flow of vehicles passing through a given point
- E.g. Ramp meters
- Capacity determined using Queueing Theory





Source: Austroads (2016)

Arrival Rate (r): Number of arrivals per unit time and its distribution

Service Rate (s): Number of departures per unit time and its distribution

Metering Point: Number of service channels. E.g. number of lanes

Queue: Vehicles waiting to be served. Arrival is generally FIFO

Metered Flow

See Section 5.1, Austroads (2020)

- Under stable traffic conditions:

$C = 3600\,.\,s$

- Assuming Poisson arrival and negative exponential service rates, we can calculate:
- Utilisation factor $\rho = r/s$
- Mean queue length $n_q = \rho/(1-\rho)$
- Mean delay $w_m = n_q/r$

Urban Arterials

See Section 5.2, Austroads (2020)

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Typical mid-block capacity of urban roads

Type of lane	One-way mid-block capacity (pc/h)
Median or inner lane	
Divided road	1000
Undivided road	900
Middle lane (of a 3 lane carriageway)	
Divided road	900
Undivided road	1000
Kerb lane	
Adjacent to parking lane	900
Occasional parked vehicles	600
Clearway conditions	900

Source: Austroads (2020)

Peak period traffic volumes can be increased between **1200** and **1400 pc/h/ln** if:

- Control or absence of parking
- Good signal coordination
- Control or absence of right turns ....

Intersection Capacity Analysis

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Unsignalised Intersections

See Section 6.1, Austroads (2020)

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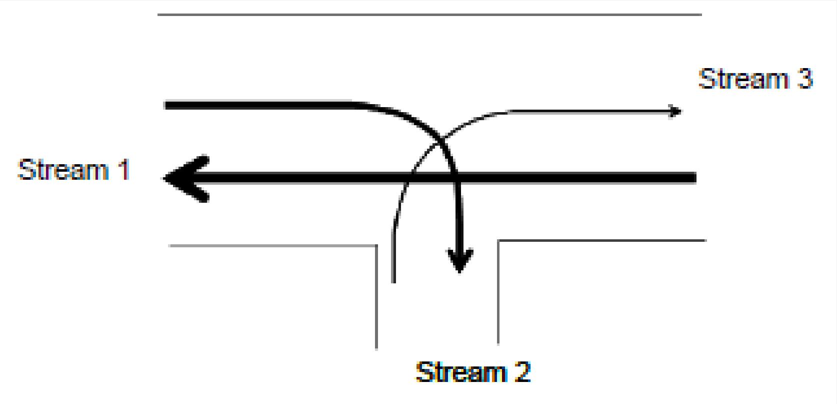
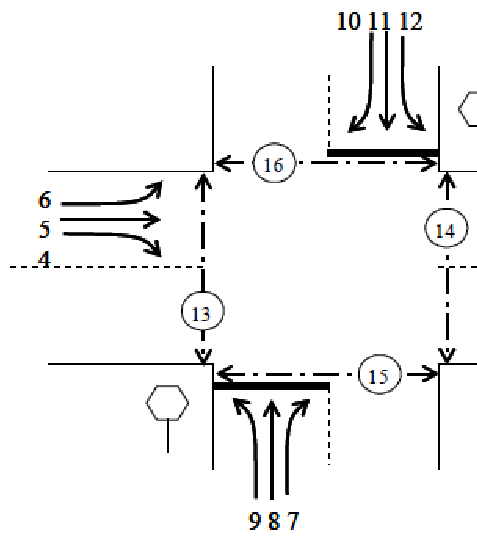
Capacity is calculated based on the total conflicting flow

Determining Conflicting Streams



Source: Austroads (2020)



Rank	Traffic streams
1	2, 3, 5, 6, 15, 16
2	1, 4, 9, 12, 13, 14
3	8, 11
4	7, 10

Source: Austroads (2020)

Unsignalised Intersections

See Section 6.1, Austroads (2020)

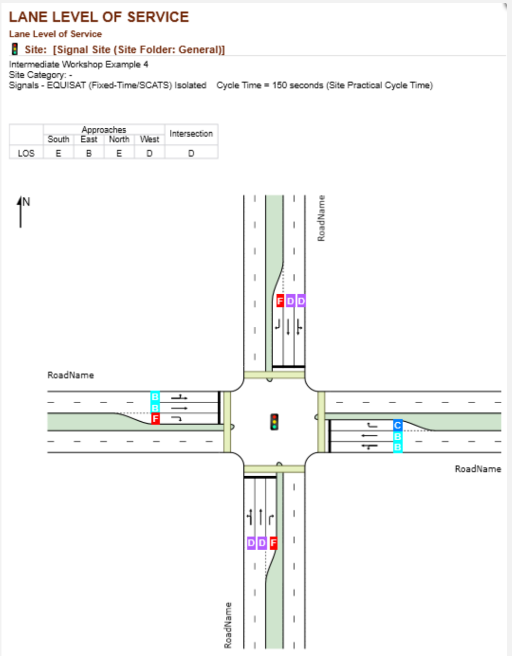
In Australia and New Zealand, the analysis of unsignalised intersections should be evaluated using SIDRA Intersection (Akçelik and Associates 2011) or an equivalent program. (Austroads, 2020)

Default parameter values used in SIDRA Intersection

Standard driving on the left model						
	2-lane major road			4-lane major road		
STOP sign	t_c	t_f	s	t_c	t_f	s
Minor road: left turn	4.5	2.5	1440	5.0	3.0	1200
• through	5.0	3.0	1200	6.5	3.5	1029
• right turn	5.5	3.5	1029	7.0	4.0	900
Right turn from major road	4.0	2.0	1800	4.5	2.5	1440
GIVE-WAY / YIELD sign	t_c	t_f	s	t_c	t_f	s
Minor road: left turn	4.0	2.2	1636	4.5	2.7	1333
• through	4.5	2.7	1333	6.0	3.2	1125
• right turn	5.0	3.2	1125	6.5	3.7	973
Right turn from major road	4.0	2.0	1800	4.5	2.5	1440

Source: Austroads (2020)

Saturation Capacity



Source: SIDRA Intersection (2020)

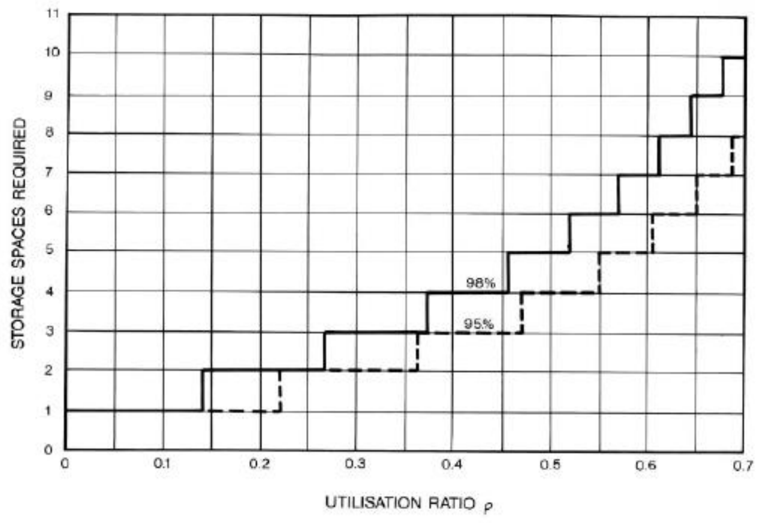
Unsignalised Intersections

See Section 6.1, Austroads (2020)

Storage Requirements: The storage length required for a right-turn movement

<u>Steps:</u>

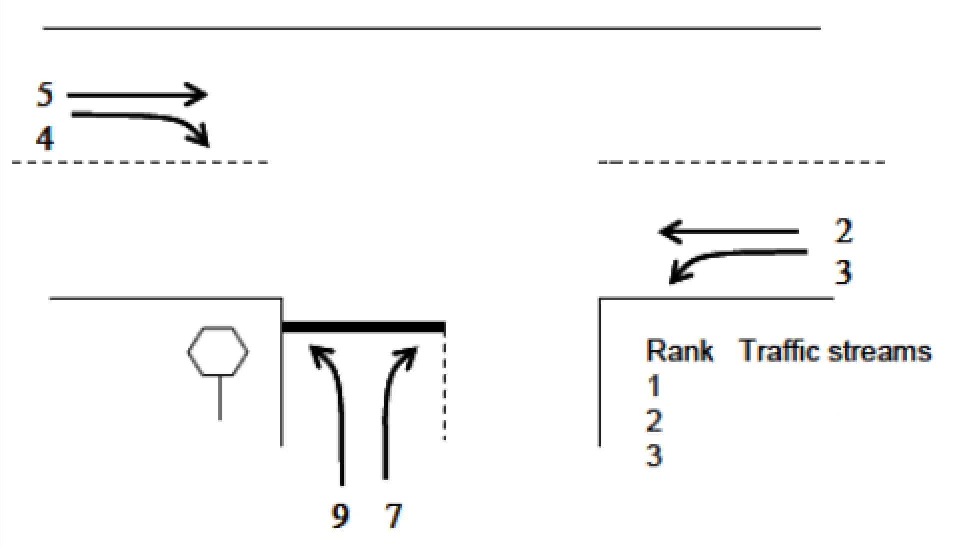
1. Determine the minor stream movement lane volume (r_m)
2. Determine the saturation flow (s) for the minor stream movement
3. Calculate the utilisation rate ($\rho = r_m/s$)
4. Look up the plot



Source: Austroads (2020)

Time to Reflect

1. Which traffic movements come under Rank 1? Mention all that apply.



Answer:

Movements 2, 3 and 5

Through (straight) and left traffic movements on the major road have the highest priority.

Roundabouts

See Section 6.2, Austroads (2020)

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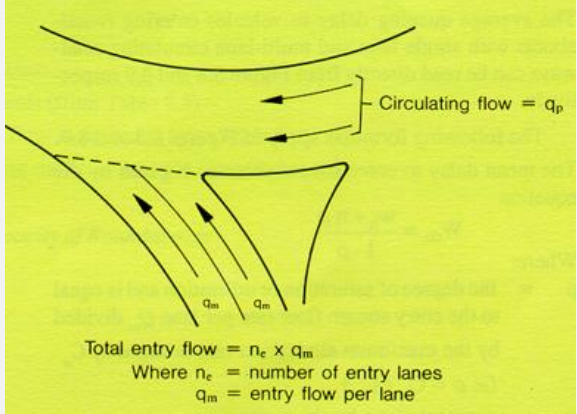
Capacity is determined using Gap Acceptance Theory



Source: HCM (2016)

q_p = circulating flow *(veh/s)*

t_a = critical acceptance gap *(s)*

t_f = follow-up headway *(s)*

τ = min headway in circulating flow *(s)*

Capacity per lane for an approach *(veh/hr/ln)*

$$C_e = \frac{3600 q_p (1 - q_p \tau) \exp(-q_p (t_a - \tau))}{1 - \exp(-q_p t_f)}$$

According to Austroads (2020):

- The capacity model in SIDRA Intersection has been calibrated using field data in Australia
- It is not recommended that the HCM 2016 procedure for roundabout analysis be used at this time.

Roundabouts

See Section 6.2, Austroads (2020)

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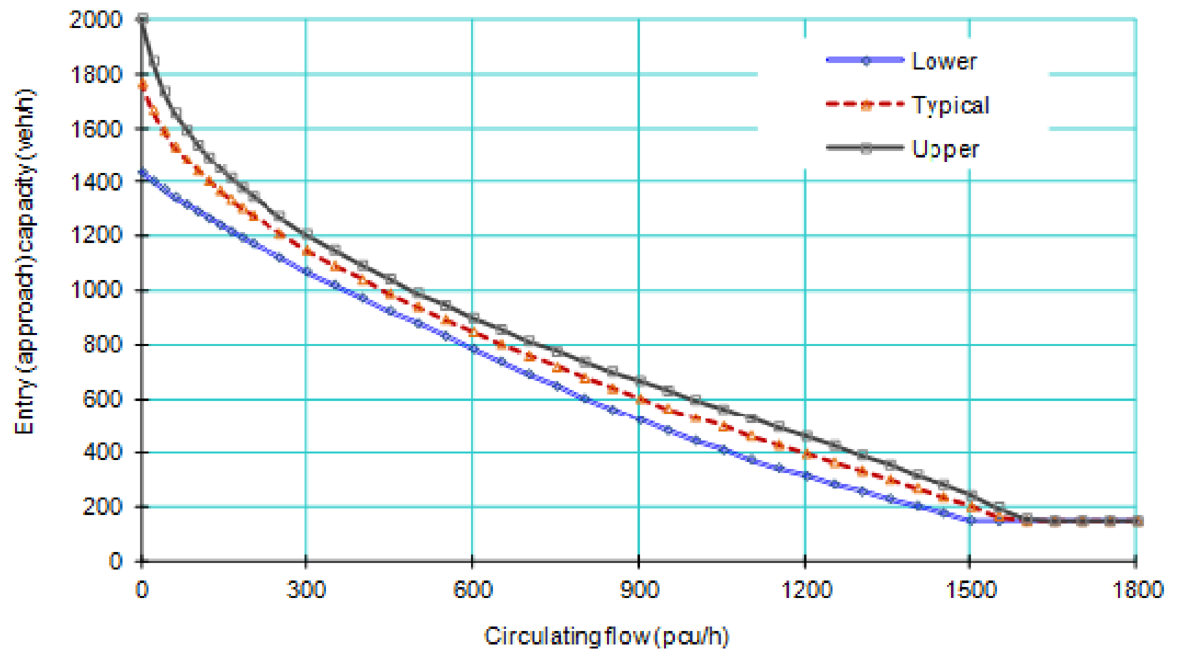
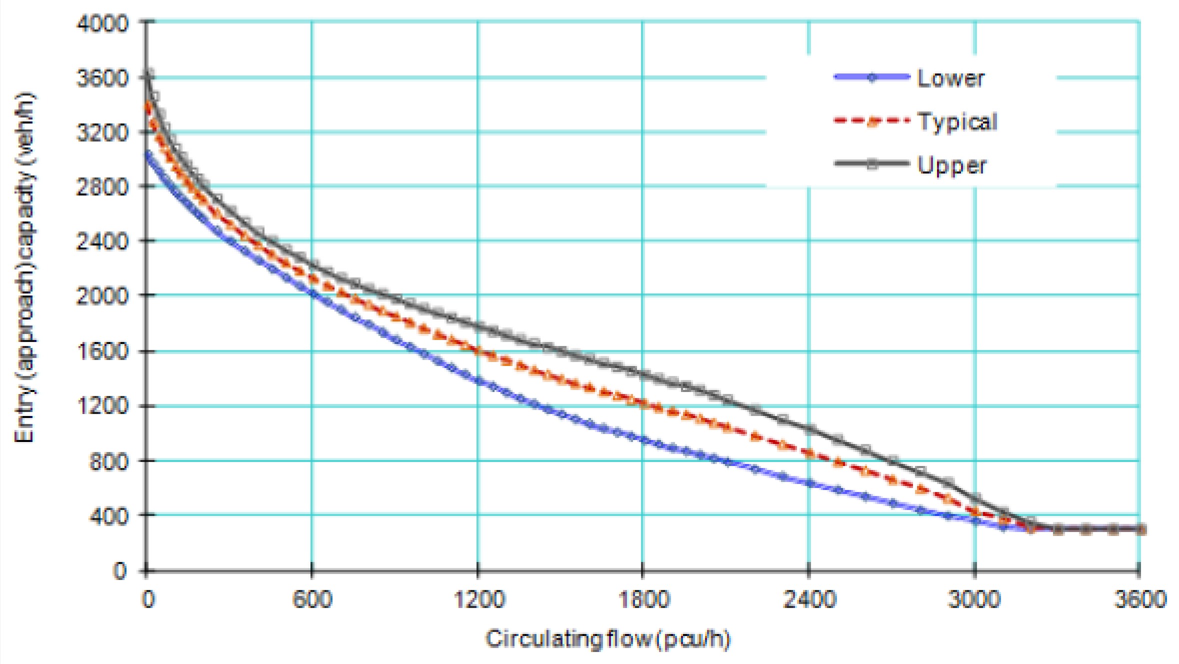
1-lane roundabout



Source: Austroads (2020)

2-lane roundabout

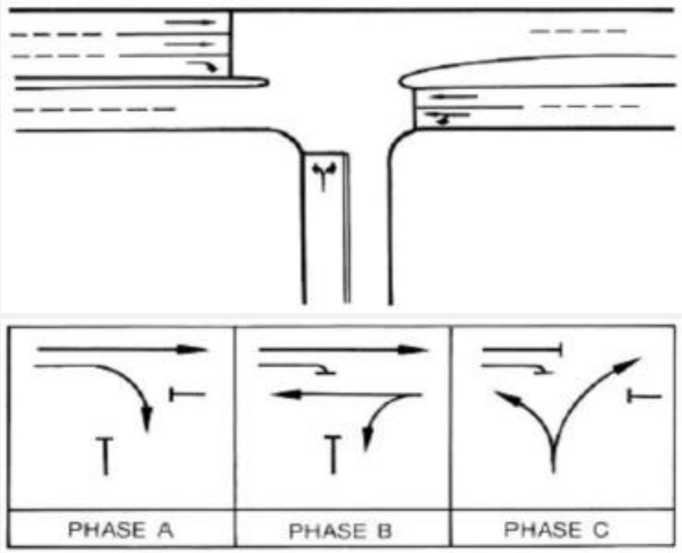


Source: Austroads (2020)

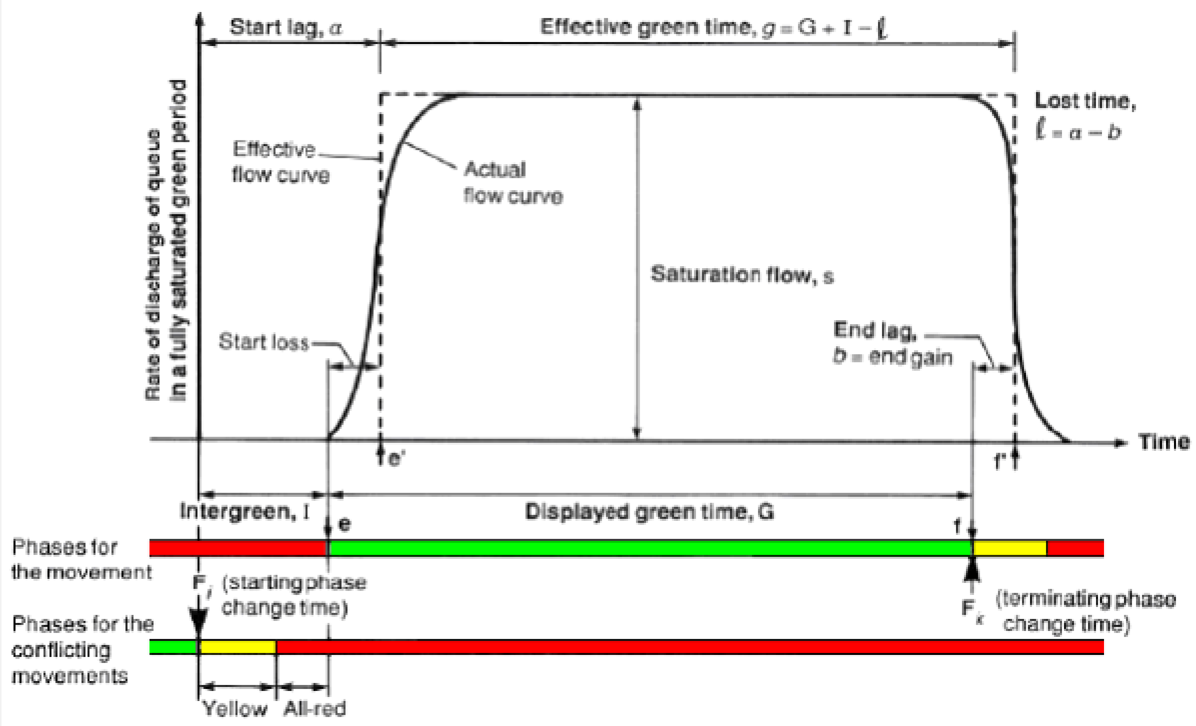
Signalised Intersections

See Section 6.4, Austroads (2020)

Capacity calculation is based on individual traffic movements (or lane groups) and approaches, rather than the intersection as a whole



Source: Austroads (2020)



Source: Austroads (2020)

Basic Capacity Model

Signalised Intersections

See Section 6.4, Austroads (2020)

Capacity Analysis:

- Capacity of a movement: $C = Sg/c$
- Green time ratio: $u = g/c$
- Flow ratio: $y = Q/S$
- Movement degree of saturation: $x = Q/C$
- For uncongested movement: $x < 1$

S = saturation flow rate (veh/h)

g = effective green time per cycle (s)

c = cycle time (s)

Q = arrival flow (veh/h)

Environment class	Basic saturation flow in tcu/h		
	Lane type 1	Lane type 2	Lane type 3
A	1850	1810	1700
B	1700	1670	1570
C	1580	1550	1270

TCU – Through Car Units

Source: Austroads (2020)

Time to Reflect

2. The saturation flow is the number of vehicles that would cross the intersection if the approach signal is left green for….

A. 60 seconds
B. Cycle time
C. 3600 seconds
D. None of these

Answer:

Option C is correct!

Saturation flow is the number of vehicles that pass the intersection if the approach signal is left green for 1 hour.

References

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Tutorial available for this learning module!

Thank you for participating

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