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An assessment of the HIGHWAY CAPACITY MANUAL EDITION 6 roundabout capacity model

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Disclaimer and Previous Paper

- The author is the developer of the SIDRA INTERSECTION model used in the study presented in this paper.
- Fundamental aspects of the HCM roundabout capacity model were discussed by the author in:

  AKÇELIK, R. (2011). An assessment of the Highway Capacity Manual 2010 roundabout capacity model. Paper presented at the International Roundabout Conference, Transportation Research Board, Carmel, Indiana, USA, May 2011.

  Available for download:
  http://www.sidrasolutions.com/Resources/Articles

Paper Content

- An assessment of the new Highway Capacity Manual Edition 6 (HCM Edition 6), Chapter 22 roundabout capacity model
- The HCM two-lane roundabout example used to compare capacity and performance estimates from the HCM Edition 6, HCM 2010 and SIDRA Standard roundabout capacity models
- SIDRA Standard model EXTENSIONS to the HCM Edition 6 model

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HCM Edition 6 Roundabout Capacity Model

HCM Edition 6 model is a non-linear empirical (regression) model with a theoretical basis in gap-acceptance methodology

$$Q_g = f_{HV}\, f_p\, A\, exp(-B\, q_m)$$

f_{HV} and f_p are heavy vehicle and pedestrian factors

$A = 3600 / t_f$

$B = (t_c - 0.5\, t_f) / 3600$

t_f : follow-up headway

t_c : critical gap (headway)

HCM Edition 6 Roundabout Capacity Model

Essentially the same model as HCM 2010 model:

"a combination of simple, lane-based regression and gap-acceptance models for both single-lane and double-lane roundabouts"

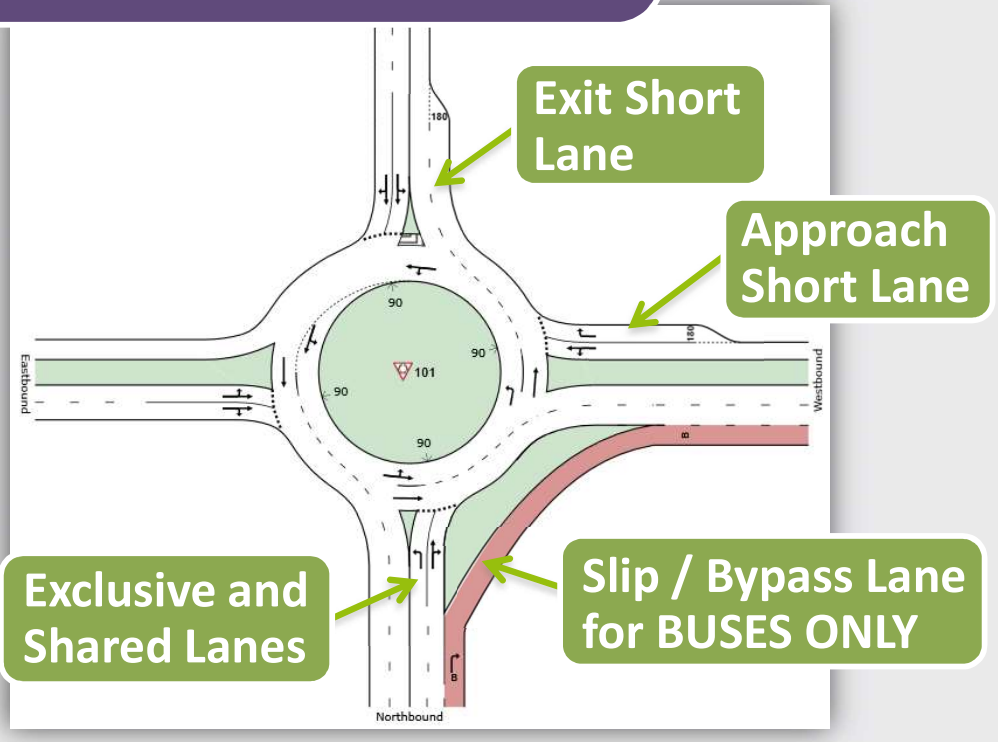
- It has the same form as the HCM 2010 model with different parameters
- For model calibration, it recommends the use of gap-acceptance parameters Critical Gap and Follow-up Headway
- It is a LANE BASED model:
  This is unlike the lane group based models used in the HCM for signals and two-way sign control

LANE-BASED Capacity and Performance Model

LANE-BASED modeling is more realistic and reliable than modeling by **approaches** and **lane groups**

- **General**:
  Unequal lane flows, De facto exclusive lanes, Short lanes, Slip/Bypass lanes
- **Roundabouts**:
  Dominant and Subdominant lanes (unequal entry lane capacities), Unequal circulating lane flows,
- **NETWORK (Corridor) Model**:
  Lane back of queue, lane blockage, capacity constraint, midblock lane changes, signal platoon arrival and departure patterns, extra bunching

Individual approach, exit and circulating lanes have different characteristics



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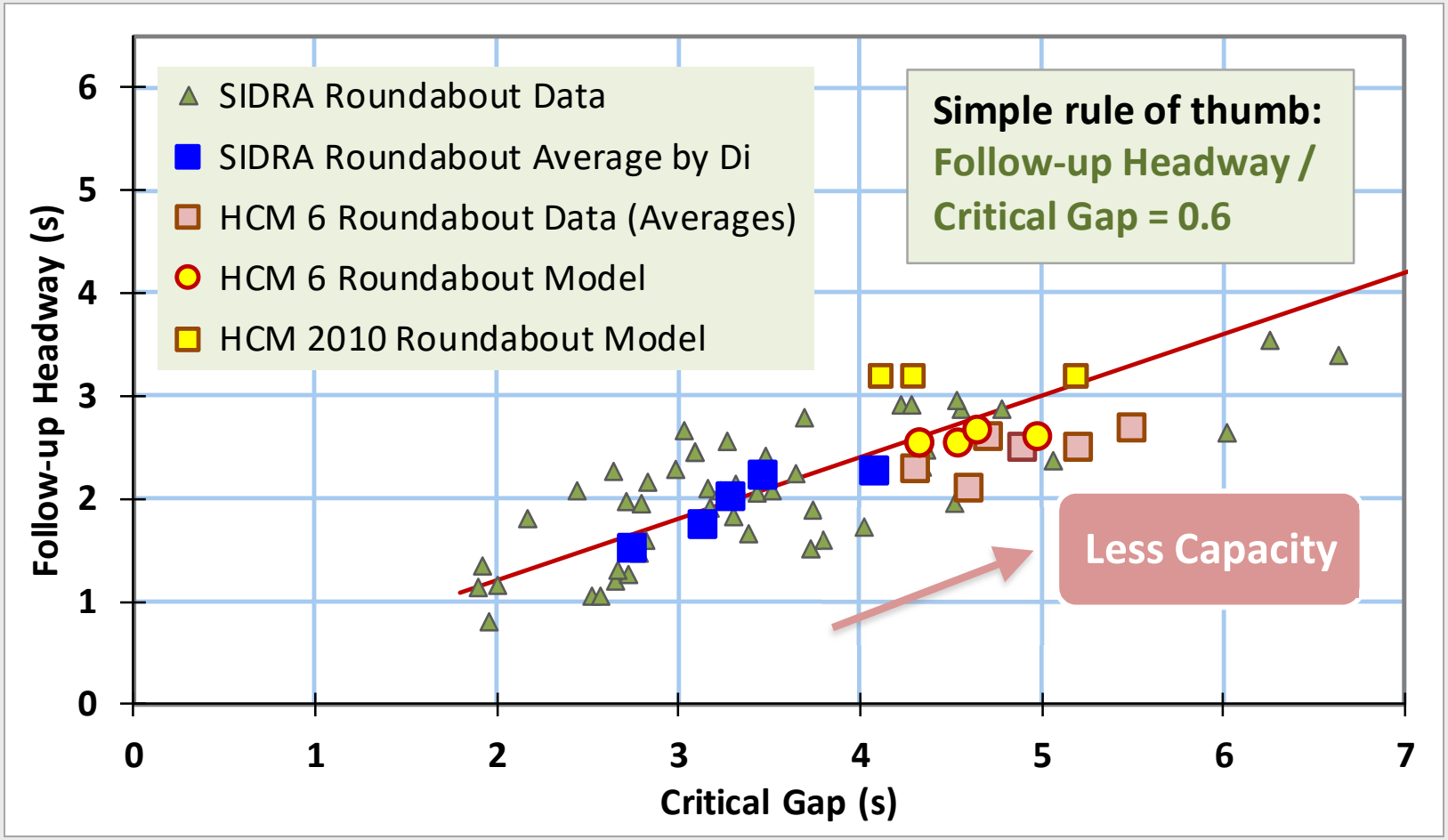
Follow-up Headway and Critical Gap Comparison

Detailed data in the paper



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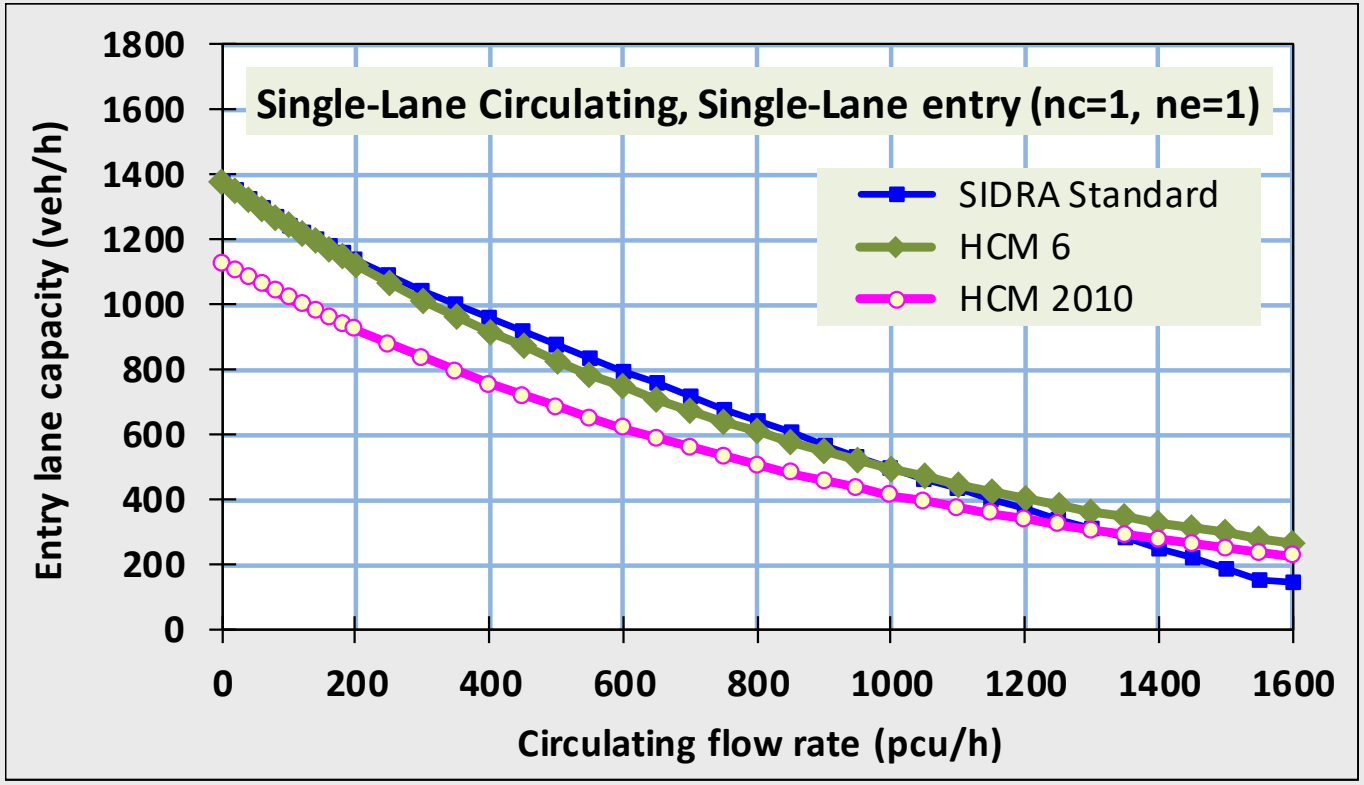
Capacity Comparison: Single-Lane Roundabouts



Inscribed Diameter = 140 ft , Lane Width = 13 ft, Entry Radius = 65 ft, Entry Angle = 30°

Environment Factor = 1.05, Entry Flow / Circulating Flow Ratio: No adjustment

Origin - Destination Factor accounting for unbalanced flow conditions: Medium effect with the factor decreasing from 1.00 at zero circulating flow to 0.7 - 0.8 at a high circulating flow rate of 1400 veh/h.

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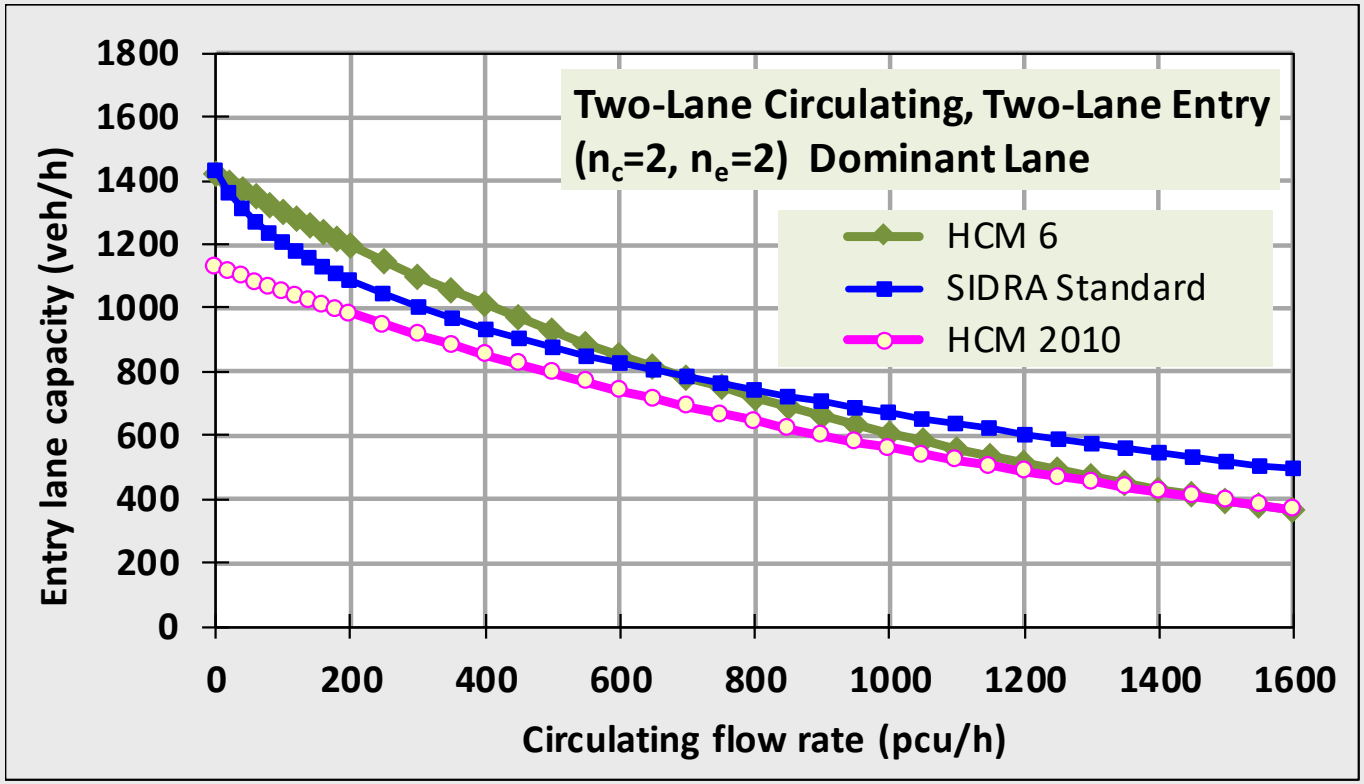
Capacity Comparison: Two-Lane Roundabouts
Dominant Lane



Inscribed Diameter = 160 ft , Lane Width = 13 ft, Entry Radius = 65 ft, Entry Angle = 30°

Environment Factor = 1.2, Entry Flow / Circulating Flow Ratio: Low adjustment

Origin - Destination Factor accounting for unbalanced flow conditions: Medium effect with the factor decreasing from 1.00 at zero circulating flow to 0.7 - 0.8 at a high circulating flow rate of 1400 veh/h.

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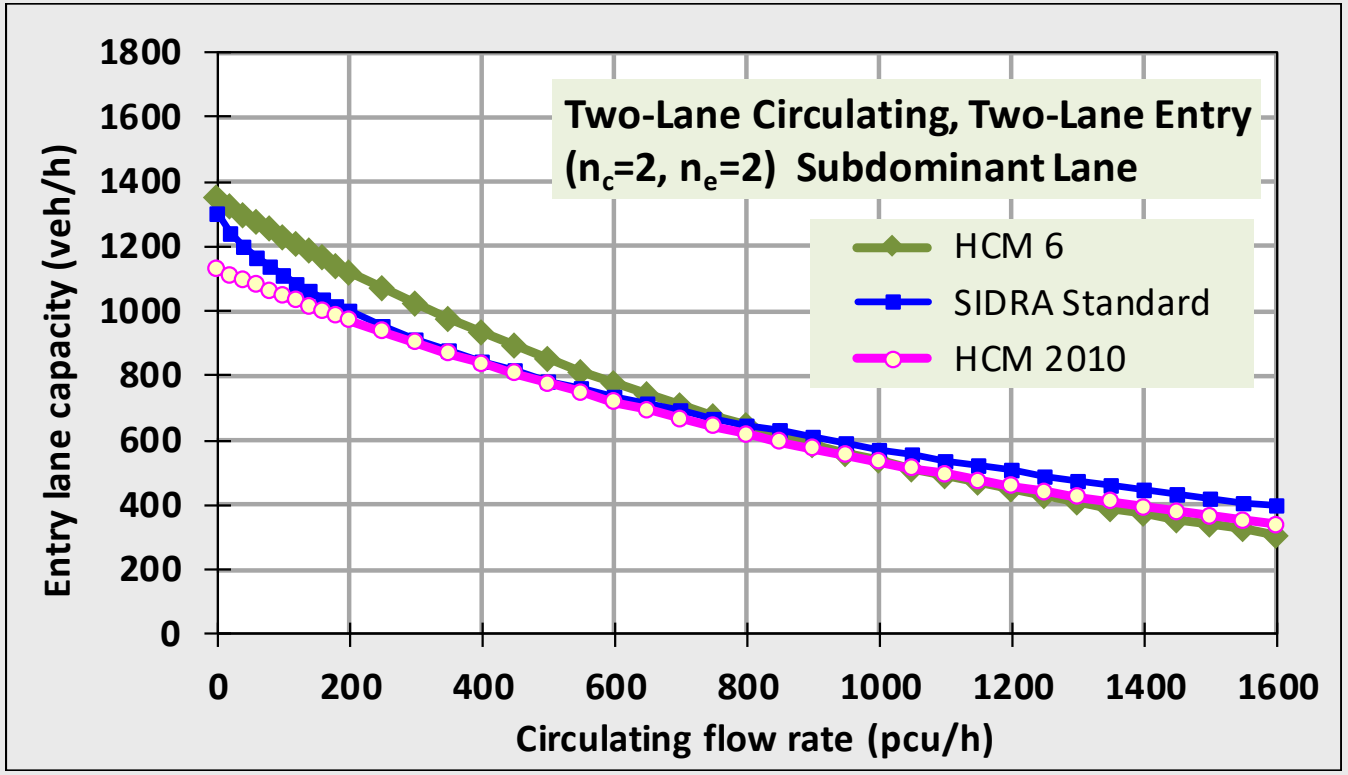
Capacity Comparison: Two-Lane Roundabouts
Subdominant Lane



Inscribed Diameter = 160 ft , Lane Width = 13 ft, Entry Radius = 65 ft, Entry Angle = 30°

Environment Factor = 1.2, Entry Flow / Circulating Flow Ratio: Low adjustment

Origin - Destination Factor accounting for unbalanced flow conditions: Medium effect with the factor decreasing from 1.00 at zero circulating flow to 0.7 - 0.8 at a high circulating flow rate of 1400 veh/h.

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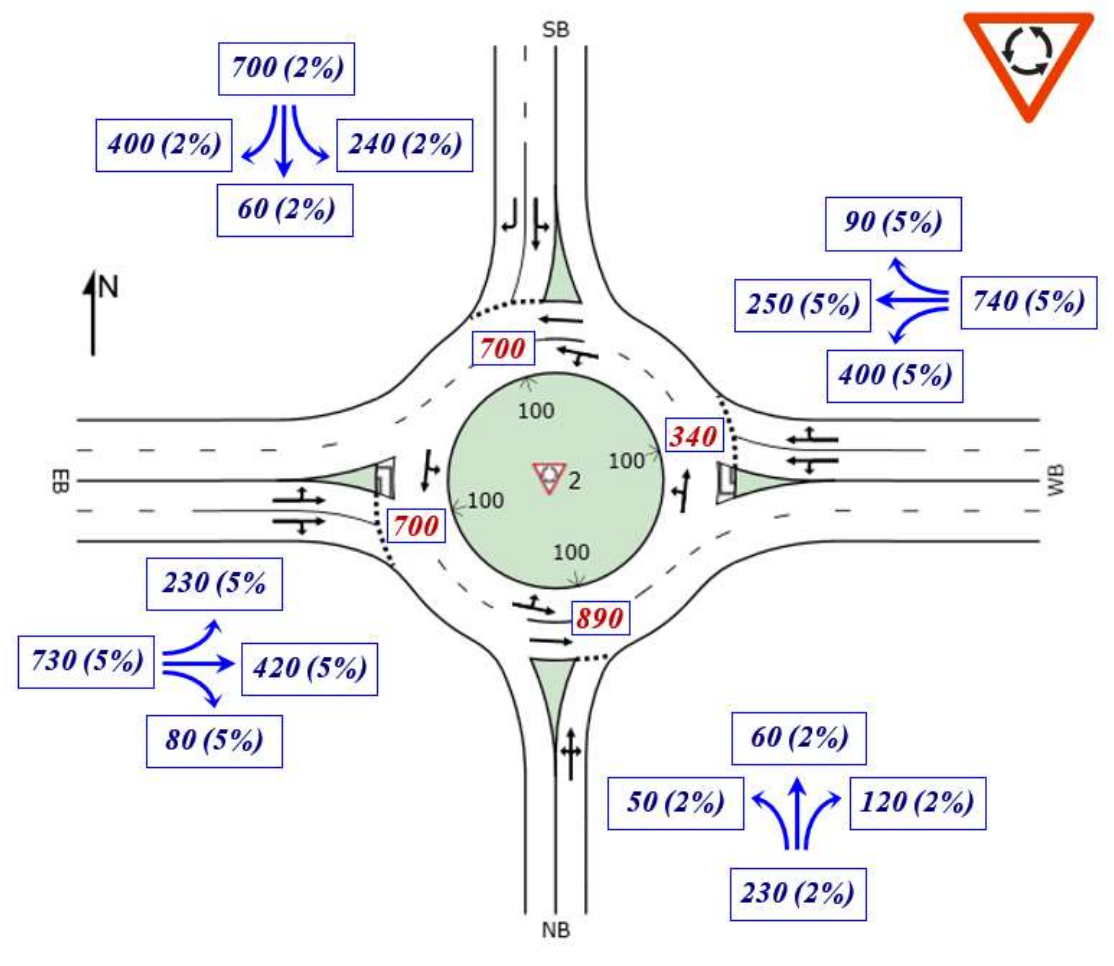
HCM Edition 6 two-lane roundabout example



- Example 2 in HCM Edition 6, Chapter 33.
- A fairly balanced origin-destination flow pattern.
- No pedestrian effects.
- PFF = 95 % (all)
- HV % values shown

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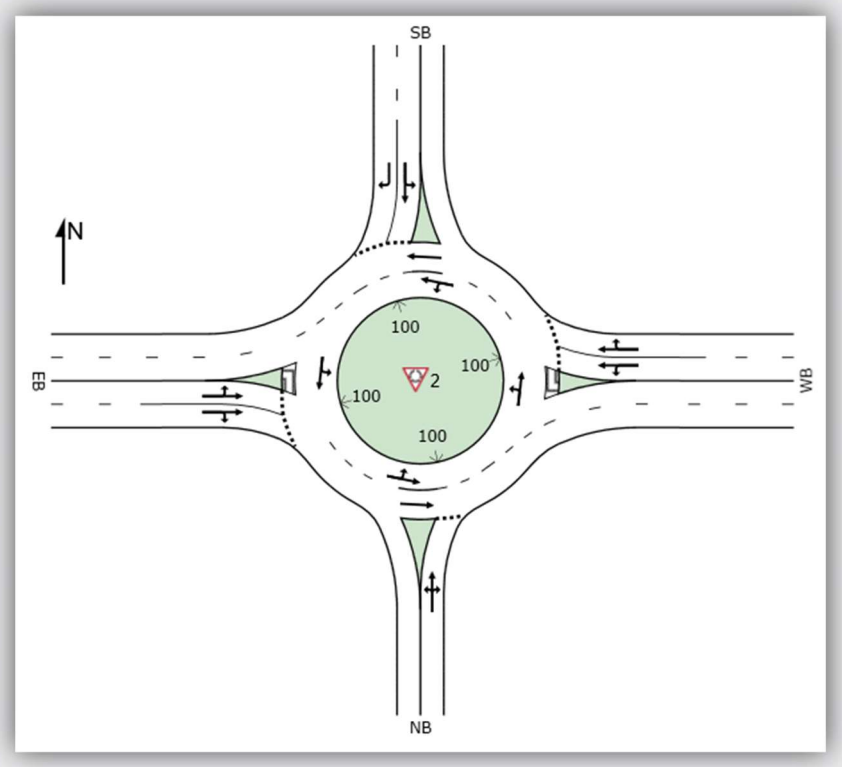
HCM Edition 6 two-lane roundabout example

Roundabout Geometry parameters: used by the **SIDRA Standard** model but not used for the **HCM Edition 6** and **HCM 2010** models

- All entry lane widths: 13 ft / 4 m
- 1-lane circulating width: 25 ft / 7.5 m
- 2-lane circulating width: 30 ft / 9.0 m
- Central island diameter: 100 ft/ 30 m
- Entry radius: 65 ft / 20 m
- Entry angle: 30 degrees



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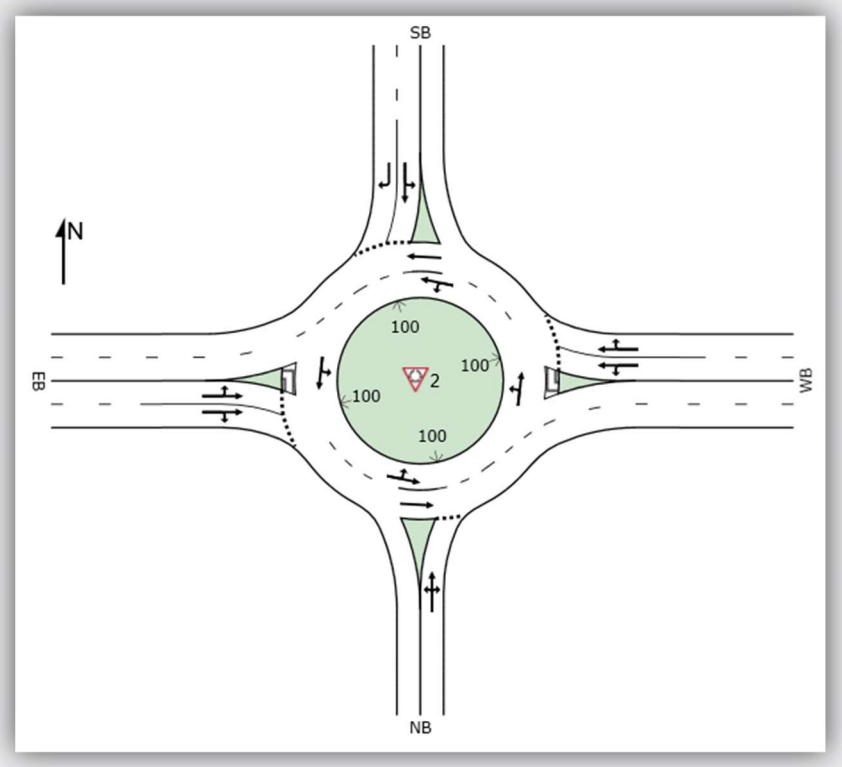
HCM Edition 6 two-lane roundabout example

Environment Factor (EF) setting for the **SIDRA Standard** model:

- **EF =1.2** is used for the North (SB) approach: (n_c = 2, n_e = 2)
- **EF = 1.05** is used for all other approaches due to the mixed one-lane and two-lane arrangements



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Comparison of Capacity, Performance and LOS results from SIDRA Standard, HCM Edition 6 and HCM 2010 Models

- **HCM Edition 6** and **SIDRA Standard** model calibrated using the Environment Factor parameter give **close capacity and performance results** although there are subtle differences between the two models
- **HCM Edition 6** and **HCM 2010** models differ significantly

Approach	Entry Lane Flow		Capacity		Degree of Satn	Average Delay	Level of Service	95% Back of Queue
	Lane 1 (Left)	Lane 2 (Right)	Lane 1 (Left)	Lane 2 (Right)				
	(veh/h)		(veh/h)		(v/c ratio)	(s/veh)		(ft)
SIDRA Standard Model (Environment Factor = 1.05 & 1.2)								
NB (South)	242	na	599	na	0.41	12.1	B	55
WB (East)	425	354	1168*	971	0.36	7.1	A	68
SB (North)	316	421	648	713*	0.59	14.2	B	102
EB (West)	335	434	678	878*	0.49	11.5	B	113
HCM Edition 6 Model								
NB (South)	242	na	607	na	0.40	11.8	B	43
WB (East)	421	358	964	964	0.44	8.3	A	57
SB (North)	316	421	650	722	0.58	14.0	B	86
EB (West)	384	384	675	675	0.57	15.0	B	84
HCM 2010 Model								
NB (South)	242	na	559	na	0.43	13.4	B	37
WB (East)	421	358	742	742	0.57	12.9	B	87
SB (North)	316	421	621	645	0.65	16.8	B	80
EB (West)	384	384	501	501	0.77	30.9	C	135

* Dominant lane

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HCM Edition 6 two-lane roundabout example
ANALYSIS OF FUTURE TRAFFIC CONDITIONS

DESIGN LIFE analysis for the example presented here:

2.5% uniform traffic growth over 10 years
(25% higher demand)

HCM Edition 6 states that "*the capacities presented here are believed to be higher primarily due to the larger and more saturated dataset and not primarily due to an increase in capacity over time.*"

Some practitioners believe that higher capacities should be applied in the analysis of future traffic as in the case of design life analysis.

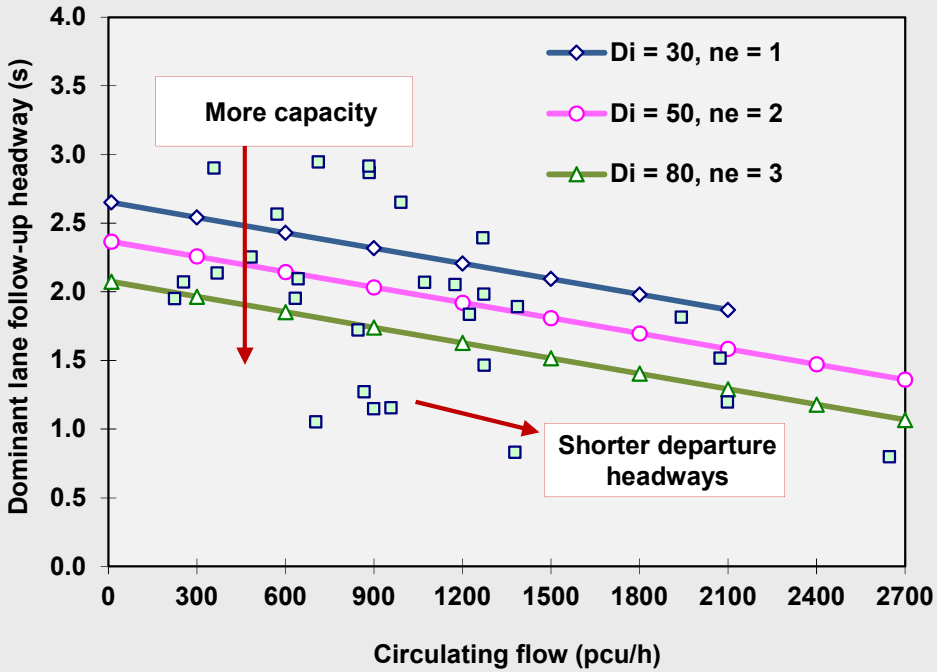
SIDRA Standard model:

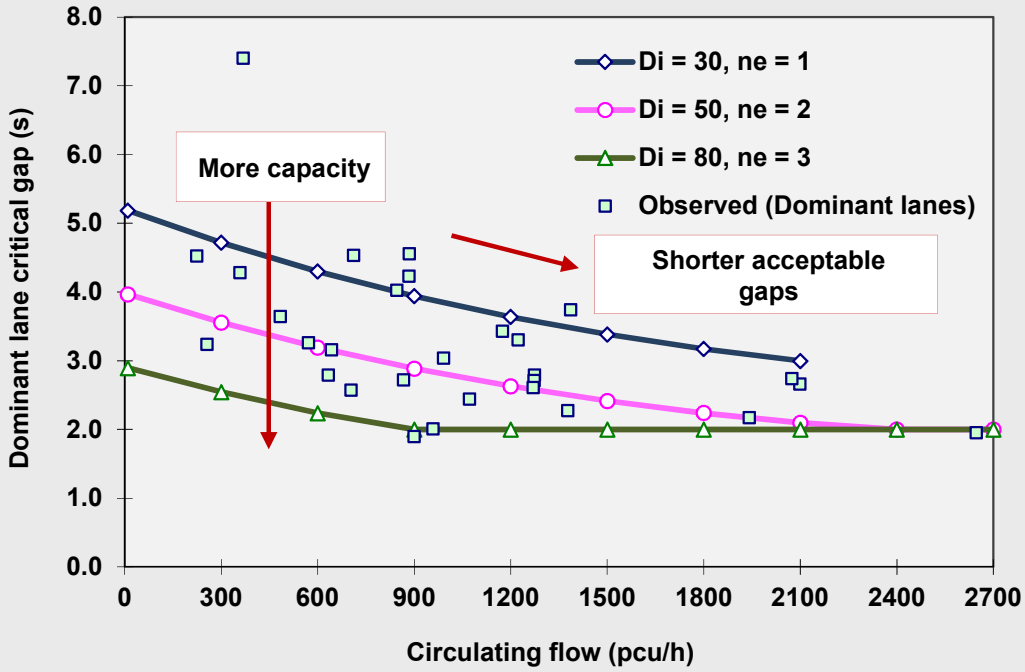
Environment Factor values of **1.0 and 1.1** instead of **1.05 and 1.2** used for reduced critical gap and follow-up headway values.

Driver Behavior and Geometry

SIDRA Standard model in DESIGN LIFE Analysis:

In addition to lower Environment Factors used, critical gap and follow-up headway are reduced due to increased circulating flow rates in Design life analysis.





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SIDRA Standard Model

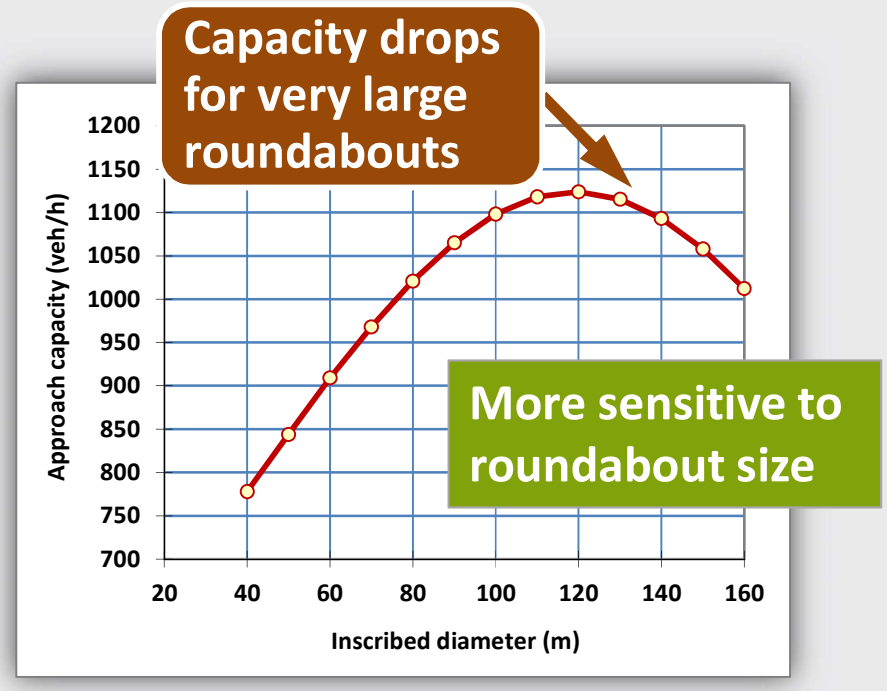
Other Model Differences between the SIDRA Standard model and HCM Edition 6 model (shortcomings of the HCM edition 6 model)

The HCM 6, Chapter 22 lists various limitations of the HCM procedures that might be addressed by alternative tools. Some of these limitations as addressed by SIDRA INTERSECTION through extensions to the *US HCM 6* and *US HCM 2010* roundabout capacity model options or as part of the *SIDRA Standard* roundabout capacity model are discussed below.

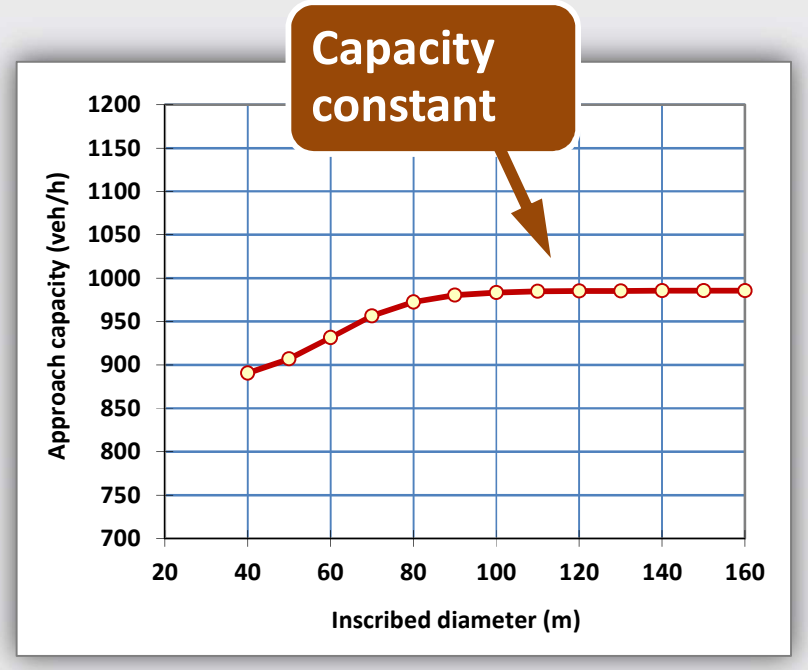
Roundabout Geometry in the SIDRA Standard Model

Follow-up headway and critical gap values are sensitive to roundabout geometry

- **Roundabout Size: Inscribed Diameter**
  (Single-lane roundabout example)



SIDRA Standard model



UK TRL model

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Roundabout Geometry in the SIDRA Standard Model

❖ Entry Radius Factor (f_r) and Entry Angle Factor (f_a)

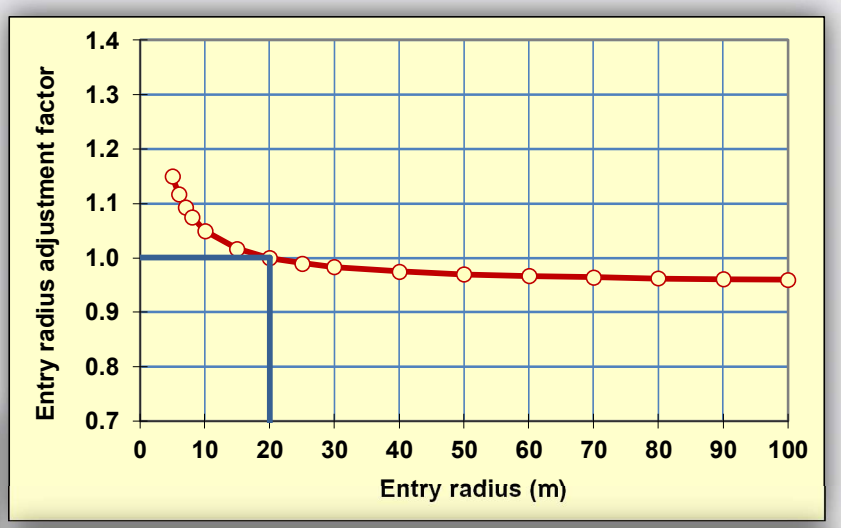
$f_r = 0.95 + 1 / r_e$

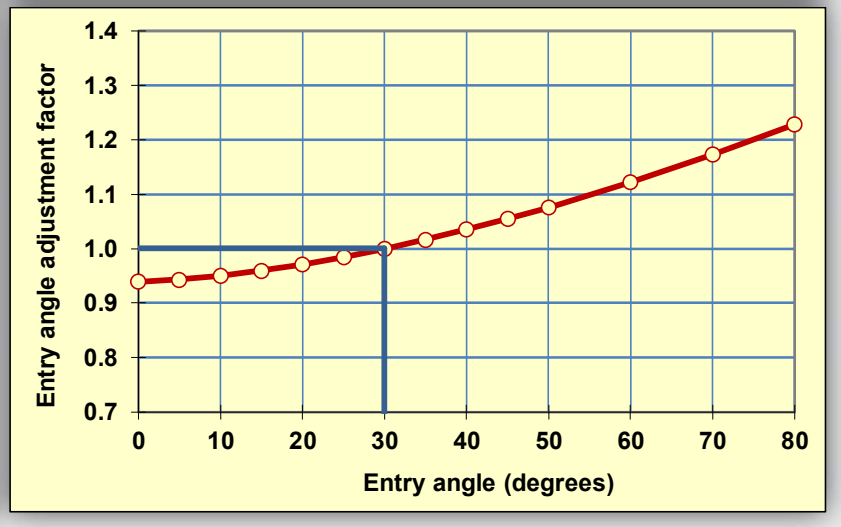
$f_a = 0.94 + 0.00026\ \phi_e\ ^{\wedge}1.6$

r_e is the entry radius (m)

ϕ_e is the entry angle (degrees)

Combined effect of r and A			TRL	SIDRA
r (m)	r (ft)	A (degrees)	a	$f_r f_a$
5	16	70	1.40	1.35
10	33	60	1.18	1.18
15	49	50	1.09	1.09
20	66	45	1.05	1.05
25	82	40	1.03	1.02
30	98	35	1.00	1.00
40	131	**30**	0.98	0.98
50	164	20	0.94	0.94
60	197	15	0.92	0.93
70	230	10	0.91	0.92
80	262	5	0.89	0.91
100	328	0	0.87	0.90





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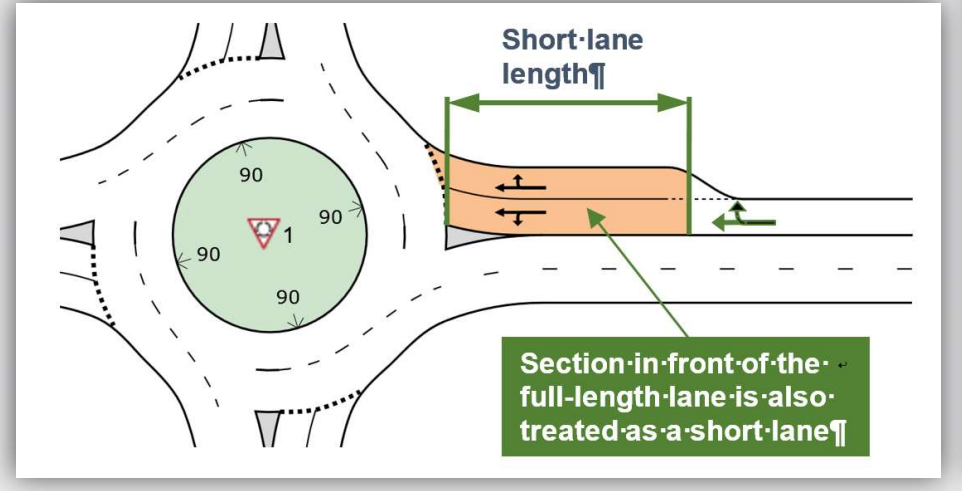
Roundabout Geometry in the SIDRA Standard Model

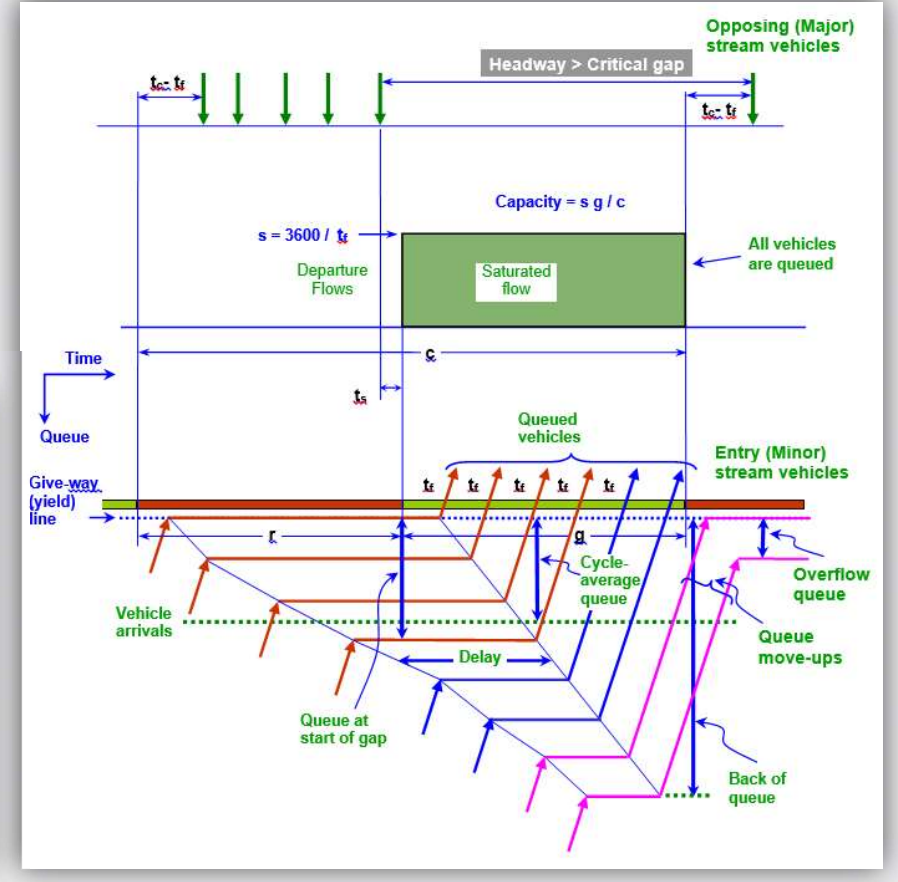
❖ Short Lane Capacities

Reduced capacity after short lane queues are discharged

Back of Queue model and Gap Acceptance Cycles used

This flow-dependent model is used rather than pure geometric model of FLARES





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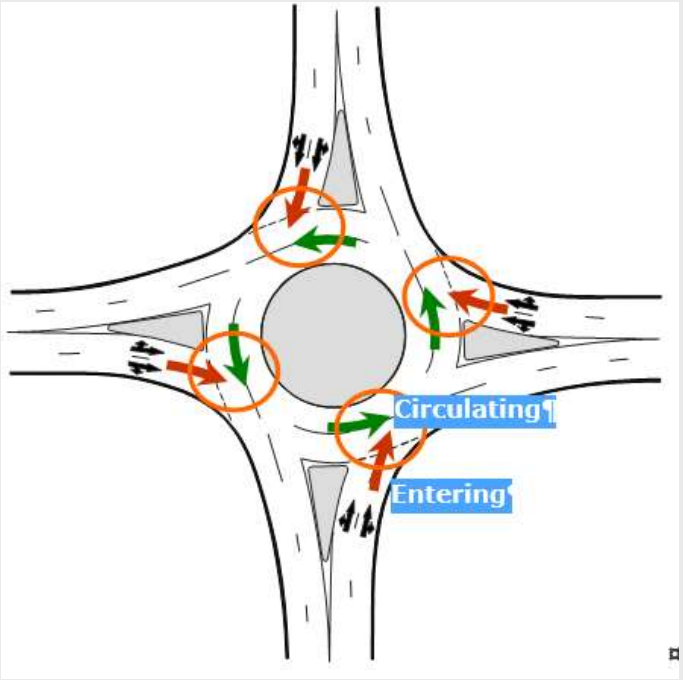
Roundabout as an Interactive System

SIDRA Standard roundabout capacity model is based on analysis of the 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 series of T intersections …



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Modeling of Circulating Lanes

HCM Edition 6 ignores modeling of circulating lane flows

- Unequal circulating lane flows
- Bunching vs random arrival headways
- Upstream signal effects using extra bunching

Circulating Lane Flow Rates

Lane No	Circulating Flow Rate veh/h	pcu/h	Percent
South: RoadName			
Lane 1	657	677	74.3
Lane 2	227	234	25.7
Approach	884	911	
East: RoadName			
Lane 1	685	705	66.4
Lane 2	346	356	33.6
Approach	1031	1061	

MODEL EXTENSIONS:
SIDRA Standard Model as an alternative tool

In addition to the aspects of roundabout capacity model discussed above:

- Capacity Constraint for oversaturated entry lanes
- Exit short lanes: effect on approach lane utilisation
- Unbalanced Flow Conditions: The Origin-Destination factor and adjustment factor for Entry /Circulating Flow Ratio
- Fuel Consumption, Emissions, Operating Cost
- Roundabout Metering Signals

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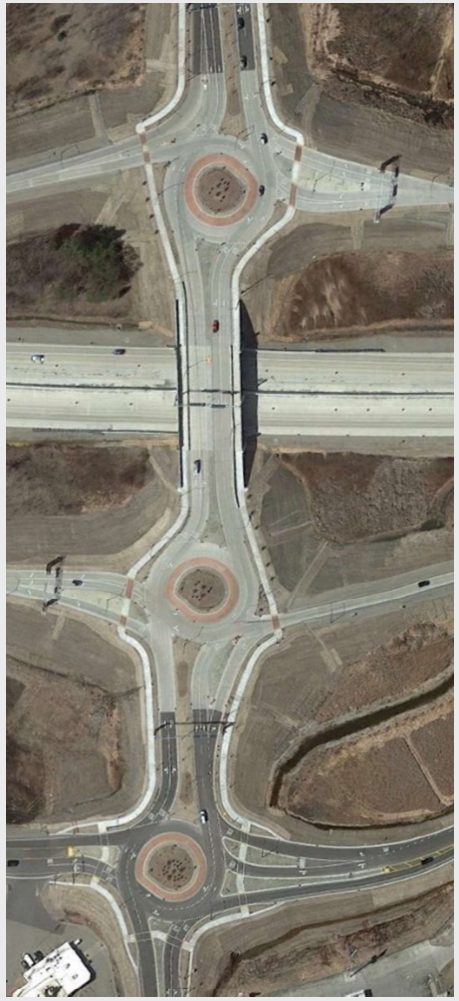
MODEL EXTENSIONS:
SIDRA INTERSECTION as an alternative tool

- More Than Two Entry and Circulating Lanes (any combination)
- Back of queue estimation for queue spillback in short lane and network modelling
- Closely-Spaced Intersections and Interchanges (NETWORK model):
  - Probability of blockage for queue spillback model
  - Capacity reduction due to spillback
  - Network Capacity Constraint (gating)



END OF PRESENTATION