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

Rahmi Akçelik
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:


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

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
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

$A = \frac{3600}{t_f}$  \[ t_f : \text{follow-up headway} \]

$B = \frac{(t_c - 0.5 t_f)}{3600}$  \[ t_c : \text{critical gap (headway)} \]
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 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
Follow-up Headway and Critical Gap Comparison

Detailed data in the paper

Simple rule of thumb: Follow-up Headway / Critical Gap = 0.6

Less Capacity
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.
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.
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.
Example 2 in HCM Edition 6, Chapter 33.

A fairly balanced origin-destination flow pattern.

No pedestrian effects.

PFF = 95% (all)

HV % values shown
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
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
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.
**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.
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.
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.
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

  - Capacity drops for very large roundabouts
  - More sensitive to roundabout size
  - Capacity constant
Roundabout Geometry in the SIDRA Standard Model

- Entry Radius Factor \( (f_r) \) and Entry Angle Factor \( (f_a) \)
  \[
  f_r = 0.95 + \frac{1}{r_e}
  \]
  \[
  f_a = 0.94 + 0.00026 \phi_e^{1.6}
  \]
  \( r_e \) is the entry radius (m)
  \( \phi_e \) is the entry angle (degrees)

<table>
<thead>
<tr>
<th>( r ) (m)</th>
<th>( r ) (ft)</th>
<th>( A ) (degrees)</th>
<th>( a )</th>
<th>( f_r f_a )</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>16</td>
<td>70</td>
<td>1.40</td>
<td>1.35</td>
</tr>
<tr>
<td>10</td>
<td>33</td>
<td>60</td>
<td>1.18</td>
<td>1.18</td>
</tr>
<tr>
<td>15</td>
<td>49</td>
<td>50</td>
<td>1.09</td>
<td>1.09</td>
</tr>
<tr>
<td><strong>20</strong></td>
<td><strong>66</strong></td>
<td><strong>45</strong></td>
<td>1.05</td>
<td>1.05</td>
</tr>
<tr>
<td>25</td>
<td>82</td>
<td>40</td>
<td>1.03</td>
<td>1.02</td>
</tr>
<tr>
<td>30</td>
<td>98</td>
<td>35</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>40</td>
<td>131</td>
<td>30</td>
<td>0.98</td>
<td>0.98</td>
</tr>
<tr>
<td>50</td>
<td>164</td>
<td>20</td>
<td>0.94</td>
<td>0.94</td>
</tr>
<tr>
<td>60</td>
<td>197</td>
<td>15</td>
<td>0.92</td>
<td>0.93</td>
</tr>
<tr>
<td>70</td>
<td>230</td>
<td>10</td>
<td>0.91</td>
<td>0.92</td>
</tr>
<tr>
<td>80</td>
<td>262</td>
<td>5</td>
<td>0.89</td>
<td>0.91</td>
</tr>
<tr>
<td>100</td>
<td>328</td>
<td>0</td>
<td>0.87</td>
<td>0.90</td>
</tr>
</tbody>
</table>
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
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 ...
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

<table>
<thead>
<tr>
<th>Lane No</th>
<th>veh/h</th>
<th>Circulating Flow Rate</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>South: RoadName</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lane 1</td>
<td>657</td>
<td>677</td>
<td>74.3</td>
</tr>
<tr>
<td>Lane 2</td>
<td>227</td>
<td>234</td>
<td>25.7</td>
</tr>
<tr>
<td>Approach</td>
<td>884</td>
<td>911</td>
<td></td>
</tr>
<tr>
<td>East: RoadName</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lane 1</td>
<td>685</td>
<td>705</td>
<td>66.4</td>
</tr>
<tr>
<td>Lane 2</td>
<td>346</td>
<td>356</td>
<td>33.6</td>
</tr>
<tr>
<td>Approach</td>
<td>1031</td>
<td>1061</td>
<td></td>
</tr>
</tbody>
</table>
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**
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

Thank you!