Some common and differing aspects of alternative models for roundabout capacity and performance estimation

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Presenter: Rahmi Akçelik

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The author is the developer of the SIDRA INTERSECTION model used in the study presented in this paper.
First about SIDRA INTERSECTION ...
## SIDRA INTERSECTION Software Status

### 1167 Organisations in 67 Countries

<table>
<thead>
<tr>
<th>Region</th>
<th>USA</th>
<th>Australia</th>
<th>South Africa</th>
<th>Canada</th>
<th>Arabian Peninsula</th>
<th>New Zealand</th>
<th>Malaysia</th>
<th>Slovenia</th>
<th>Singapore</th>
<th>Spain</th>
<th>Norway</th>
<th>Italy</th>
<th>Chile</th>
<th>Turkey</th>
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</table>

**Latest Version 5.1, 5.0, 4.0 and 3.x Users Only (15 April 2011)**

### Over 7600 Licences

<table>
<thead>
<tr>
<th>Region</th>
<th>USA</th>
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<th>Singapore</th>
<th>Norway</th>
<th>Italy</th>
<th>Chile</th>
<th>Turkey</th>
<th>Other Asia and Africa</th>
<th>Other Europe</th>
<th>Other Latin America</th>
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<td>87</td>
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</tbody>
</table>

**Unique 5.1, 5.0, 4.0 and 3.x Users Only (15 April 2011)**

- **USA**: 393 licences
- **Australia**: 275 licences
- **South Africa**: 76 licences
- **Canada**: 67 licences
- **Arabian Peninsula**: 49 licences
- **New Zealand**: 48 licences
- **Malaysia**: 38 licences
- **Slovenia**: 30 licences
- **Singapore**: 18 licences
- **Spain**: 18 licences
- **Norway**: 16 licences
- **Italy**: 15 licences
- **Chile**: 8 licences
- **Turkey**: 6 licences
- **Other Asia and Africa**: 44 licences
- **Other Europe**: 43 licences
- **Other Latin America**: 23 licences
Recent developments

SIDRA INTERSECTION 5.1 released a month ago
new ...

**INPUT COMPARISON** program for data auditing

**SIDRA UTILITIES** (programs and Excel applications):
- **VOLUMES** and **ANNUAL SUMS** Excel Applications
- **OUTPUT COMPARISON**
- **VARIABLE RUN**
- **INPUT COMPARISON**

**Application Programming Interface (API)**
- Enables interfacing other programs to **SIDRA INTERSECTION**
Interlinking with major software packages

To be released with TORUS 3
Interlinking with major software packages

VISUM

ANM

VISSIM

Work in progress
MODELING: Roundabout Metering Signals

Unbalanced flow conditions
SIDRA NETWORK >> SIDRA INTERSECTION 6.0

• Backward spread of congestion (queue blockage)
• Capacity constraint
Roundabout capacity models

The aim of the paper is to enhance understanding of the fundamental aspects of different roundabout capacity models available around the world.

Three well-known analytical models of roundabout capacity are considered:

- USA: HCM 2010 (Highway Capacity Manual 2010) model
- Australia: SIDRA INTERSECTION model, and
- UK: TRL (linear regression) model (RODEL /ARCADY).

These models have some common features as well as significant differences.
Roundabout capacity models

• A detailed **table comparing the features of the three capacity models** presented.

• The UK TRL and SIDRA Standard models compared in relation to several **geometric parameters** (entry radius, entry angle, inscribed diameter and flaring).

• A **multi-lane roundabout example** used for detailed comparison of estimates of capacity and degree of saturation (v/c ratio) produced by these.

No model is perfect ...

There is no more common error than to assume that, because prolonged and accurate mathematical calculations have been made, the application of the result to some fact of nature is absolutely certain.

Alfred N. Whitehead (1861-1947), English mathematician and philosopher
Roundabout capacity models in SIDRA INTERSECTION

Australia

NAASRA 1986

AUSTROADS 1993

SIDRA INTERSECTION

Options:
- SIDRA Standard
- HCM 2010

USA

HCM 2010

HCM 2000

FHWA 2000

Empirical LANE-BASED

Exponential regression/Gap acceptance (NCHRP 572)

Fixed gap-acceptance parameters

Fixed gap-acceptance parameters

Empirical LANE-BASED

Empirical APPROACH-BASED

Germany

Linear Regression

• Gap Acceptance
• Linear Regression

Linear Regression

Gap-acceptance parameters depend on:
- Geometry
- Flow rates

Australia

Fixed gap-acceptance parameters
Capacity of roundabouts: SIMPLE!

- Roundabout is an intersection
- Intersection is an interrupted facility
- Interruption means time loss due some form of control: YIELD at roundabout
- Thus, capacity, Q (veh/h):

  \[ Q = s \ u \]

  - \( s \) = saturation (queue discharge) flow rate (veh/h)
  - \( u \) = proportion of time when the vehicles can depart from the queue (signals are green or gaps are available in the opposing stream).
Capacity of roundabouts

Saturation flow rate \( (s) \) is the maximum flow rate that can be sustained when there is a queue and the vehicles can depart from the queue, i.e. signals are not red or the gaps in the opposing stream are not too short.

In gap-acceptance methodology, the follow-up headway, \( t_f \) corresponds to a saturation flow rate which is the maximum gap-acceptance capacity that can be achieved when the opposing flow is close to zero (y intercept):

\[
s = \frac{3600}{t_f}
\]
Roundabout capacity

Capacity, $Q = u \cdot s$

$s = \frac{3600}{t_f}$

Capacity at zero opposing flow

Capacity reduced with increased opposing flow rate due to decreased unblocked time (less gaps available)

Capacity reduced with increased critical gap value due to decreased unblocked time (more gaps rejected)

$Q =$ Capacity
$u =$ Unblocked time ratio
$t_f =$ Follow-up headway
$s =$ Saturation flow rate

Opposing flow rate
### Comparison of main model features

#### Categories of features compared
(Refer to the detailed table given in the paper)

- Methodology (lane-based / approach-based)
- Individual Entry and Circulating Lanes
- Lane Utilization for Multilane Approaches
- Volume / Capacity Ratio (critical lane or approach)
- Unbalanced Flows (Origin-Destination flow patterns)
- Driver Behavior Parameters
- Roundabout Geometry Parameters
- Heavy Vehicles
- Model Calibration
These cannot be modeled using an approach-based method

- Lane flows
- Unequal lane use
- De facto exclusive lanes
- Approach short lanes
- Exit short lanes (lane use effects)
- Circulating lane use

Effectiveness of flaring (short lanes) depends on flow conditions
**Entry Radius and Entry Angle in *SIDRA Standard* model**

\[ f_r = 0.95 + \frac{1}{r_e} \]
\[ f_a = 0.94 + \frac{0.00026}{\phi_e^{1.6}} \]

- \( r_e \) is the entry radius (m)
- \( \phi_e \) is the entry angle (degrees)

**Customary units:**
\[ f_r = 0.95 + 3.28 / r_e \]
\( r_e \) is the entry radius (ft)

### The entry radius and entry angle factors in *SIDRA Standard* and *UK TRL* models

<table>
<thead>
<tr>
<th>( r_e ) (m)</th>
<th>( r_e ) (ft)</th>
<th>( \phi_e ) (degrees)</th>
<th>UK TRL</th>
<th>SIDRA Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>18</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><strong>20</strong></td>
<td><strong>66</strong></td>
<td><strong>45</strong></td>
<td><strong>1.05</strong></td>
<td><strong>1.05</strong></td>
</tr>
<tr>
<td>30</td>
<td>98</td>
<td>35</td>
<td>1.00</td>
<td>1.00</td>
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<tr>
<td>40</td>
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<td>60</td>
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<td>0.93</td>
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<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 Size: Inscribed Diameter

SIDRA Standard model

- Capacity drops for very large roundabouts

UK TRL model (RODEL, ARCADY)

- Capacity does not drop
Model calibration issue with the TRL model

A “fatal flaw”: when the y-intercept is fixed:

Capacity decreases with improved geometry (increased entry radius, decreased entry angle, etc) if the capacity at zero circulating flow (y intercept) is fixed.

Problematic nature of the UK TRL model when the y intercept is fixed for calibration purposes

$$A = \frac{3600}{t_f}$$

Capacity

Capacity at zero opposing flow (y intercept) fixed

y intercept not fixed

Poorer geometry gives increased capacity due to fixed y intercept and lower slope

Poorer geometry gives reduced capacity since model is free to determine a lower y-intercept value (compensates for lower slope)

Opposing flow rate
Example to test different lane configurations

Two-lane circulating road and shared approach lanes

Single-lane circulating road and exclusive approach lanes

These are not design drawings – no path overlap analysis, etc please!
Capacity models used

- HCM 2010 >> SIDRA INTERSECTION 5.1
- SIDRA Standard for US* >> SIDRA INTERSECTION 5.1
- TRL (linear regression) ** >> Excel application.

* Environment Factor = 1.2
** Capacity at zero circulating flow (y intercept) = 0
Example to test different lane configurations

<table>
<thead>
<tr>
<th>Approach</th>
<th>Total Approach Flow (veh/h)</th>
<th>Circulating Flow (pcu/h)</th>
<th>Critical Lane Flow (veh/h)</th>
<th>Critical Lane Capacity (veh/h)</th>
<th>Degree of saturation (V/C ratio)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case (i): Two-lane circulating road and shared approach lanes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>HCM 2010 Capacity Model</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NB (South)</td>
<td>1150</td>
<td>360</td>
<td>2 (R) [1]</td>
<td>600 [1]</td>
<td>878</td>
</tr>
<tr>
<td>WB (East)</td>
<td>1030</td>
<td>550</td>
<td>2 (LT)</td>
<td>522</td>
<td>769</td>
</tr>
<tr>
<td>EB (West)</td>
<td>660</td>
<td>850</td>
<td>2 (TR)</td>
<td>337</td>
<td>623</td>
</tr>
<tr>
<td><strong>SIDRA Standard Capacity Model (Environment Factor = 1.2)</strong></td>
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<td></td>
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</tr>
<tr>
<td>NB (South)</td>
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<td>360</td>
<td>2 (R) [1]</td>
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<td>887</td>
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<tr>
<td>WB (East)</td>
<td>1030</td>
<td>550</td>
<td>2 (LT)</td>
<td>515</td>
<td>719</td>
</tr>
<tr>
<td>EB (West)</td>
<td>660</td>
<td>850</td>
<td>2 (TR)</td>
<td>330</td>
<td>604</td>
</tr>
<tr>
<td><strong>UK TRL Model (Capacity at Zero Circulating Flow = 1130)</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NB (South)</td>
<td>1150</td>
<td>360</td>
<td>Average</td>
<td>575</td>
<td>991</td>
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<tr>
<td>WB (East)</td>
<td>1030</td>
<td>550</td>
<td>Average</td>
<td>515</td>
<td>917</td>
</tr>
<tr>
<td>EB (West)</td>
<td>660</td>
<td>850</td>
<td>Average</td>
<td>330</td>
<td>801</td>
</tr>
</tbody>
</table>
### Example to test different lane configurations

<table>
<thead>
<tr>
<th>Approach</th>
<th>Total Approach Flow (veh/h)</th>
<th>Circulating Flow (pcu/h)</th>
<th>Critical Lane</th>
<th>Critical Lane Flow (veh/h)</th>
<th>Critical Lane Capacity (veh/h)</th>
<th>Degree of saturation (v/c ratio)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Case (ii): Single-lane circulating road and exclusive approach lanes</strong></td>
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<td></td>
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<tr>
<td><strong>HCM 2010 Capacity Model</strong></td>
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</tr>
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<tr>
<td>WB (East)</td>
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<td>1.30</td>
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<td>EB (West)</td>
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<td>652 [2]</td>
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<td><strong>SIDRA Standard Capacity Model (Environment Factor = 1.2)</strong></td>
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<td>850</td>
<td>Average</td>
<td>330</td>
<td>801</td>
<td>0.41</td>
</tr>
</tbody>
</table>

*No change!*
Importance of LANE-BY-LANE model

Problem originally identified by Barbara Chard (UK)

Refer to:

Also:
Recommended investigation: microsimulation model challenge

Analyse this example using microsimulation:

- Identify the difference between cases i and ii using microsimulation.
- Analyse this example further for varying geometry parameters:

<table>
<thead>
<tr>
<th>Entry lane width</th>
<th>Central island diameter</th>
<th>Circulating road width 1-lane</th>
<th>Inscribed diameter (1-lane circulating)</th>
<th>Circulating road width 2-lane</th>
<th>Inscribed diameter (2-lane circulating)</th>
<th>Entry radius</th>
<th>Entry angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default values</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13 ft (4.0 m)</td>
<td>100 ft (30 m)</td>
<td>25 ft (7.5 m)</td>
<td>150 ft (45 m)</td>
<td>30 ft (9 m)</td>
<td>160 ft (48 m)</td>
<td>65 ft (20 m)</td>
<td>30°</td>
</tr>
<tr>
<td>Less favorable values</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.5 ft (3.8 m)</td>
<td>80 ft (24 m)</td>
<td>21 ft (6.5 m)</td>
<td>122 ft (38 m)</td>
<td>26 ft (8 m)</td>
<td>132 ft (41 m)</td>
<td>50 ft (16 m)</td>
<td>40°</td>
</tr>
<tr>
<td>More favorable values</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 ft (4.3 m)</td>
<td>120 ft (36 m)</td>
<td>28 ft (8.5 m)</td>
<td>176 ft (53 m)</td>
<td>33 ft (10 m)</td>
<td>186 ft (56 m)</td>
<td>100 ft (30 m)</td>
<td>20°</td>
</tr>
</tbody>
</table>
END OF PRESENTATION

Thank you ...