Roundabout Capacity and Performance

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Note 30 Jul 2011: “aaSIDRA” software is now called SIDRA INTERSECTION, and website: www.sidrasolutions.com
Presentation schedule

- Research Summary
- Roundabout Capacity and Performance Modeling:
  - ISSUES
  - DISCUSSION
- About Australia
- About aaSIDRA
We know traffic
Roundabouts: capacity and performance

- Extensive research and development work
- Heavily directional (dominant) origin-destination movements (congestion)
Roundabout Metering Signals
(current research)
Comparisons of the aaSIDRA, other Australian and the UK capacity and delay models:

Roundabout Capacity and Performance Modeling: ISSUES
Estimating roundabout entry lane capacity and performance measures

- Analytical models (not simulation)
A good method for predicting capacity and performance of modern roundabouts should model:

- DRIVER “YIELD” BEHAVIOUR and
- ROUNDABOUT GEOMETRY.

aaSIDRA model satisfies both criteria using a gap-acceptance based method to model driver yield behaviour, at the same time allowing for the effects of geometric variables. UK linear regression model used in the RODEL and ARCADY programs uses only the geometric variables.
“Yield” means gap-acceptance! (applicable to roundabouts, signals, sign control, freeway merge)

Gap-acceptance model is EMPIRICAL in calibrating driver behaviour parameters:
- entry stream characteristics
- opposing / circulating stream characteristics
aaSIDRA "parameter sensitivity" facility can be used to obtain graphs of how capacity and a large number of performance parameters (delay, queue length, cost, etc) change with roundabout geometry and driver behaviour (gap-acceptance parameters).
Modeling interactions amongst approach flows

Modeling the roundabout as a series of T-junctions is inadequate (heavy and unbalanced demand flows require modeling of origin-destination and queuing effects).
Approach lane use characteristics of the traffic streams that constitute the circulating flow.

Part of circulating flow from NORTH in one lane.

Part of circulating flow from WEST in two lanes.

Entry flow.

Approach lane use effect on circulating stream characteristics at a multilane roundabout.
Ignoring approach flow interactions cause overestimation of capacity (underestimation of delays and queue lengths)

\[ nc = 1 \ (Qg) \]
\[ nc = 2 \ (Qg) \]
\[ nc = 1 \ (Qe) \]
\[ nc = 2 \ (Qe) \]

\[ n_c = 1: D_i = 40 \text{ m} \]
\[ n_c = 2: D_i = 50 \text{ m} \]
\[ p_{cd} = 0.50, \ p_{cd} = 0.80 \]

\[ \text{Gap acceptance capacity (veh/h)} \]
\[ \text{Circulating flow (pcu/h)} \]
### Issue: Analysis detail (level of aggregation)

<table>
<thead>
<tr>
<th>Individual vehicles</th>
<th>Microsimulation models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drive cycles</td>
<td>aaSIDRA</td>
</tr>
<tr>
<td>Traffic flows</td>
<td>Most traffic analysis models</td>
</tr>
<tr>
<td>Speed-flow functions</td>
<td>Most transport planning models</td>
</tr>
<tr>
<td>Approaches</td>
<td>Lane groups</td>
</tr>
<tr>
<td></td>
<td>Individual LANES</td>
</tr>
</tbody>
</table>

- More detailed model of road geometry

- UK "empirical model" falls in this category
Lane-by-lane analysis

- aaSIDRA is the only widely-used analytical software that uses the lane-by-lane analysis including short lanes.

SPATIAL MODEL rather than LINKS or LANE GROUPS
Basic concepts of traffic analysis

**Demand**
- Arrival flow
  - Random vs Platooned
  - Peaking

**Control**
- Queue
  - Traffic signal
  - Gap acceptance

**Departure flow**
- Constant sat. flow and lost time
- Exponential discharge flow rate

**Capacity**
- Performance measures
- Level of service

**Non-Overflow** (low demand)
- Overflow (random or oversaturation)

We know traffic
Issue: Capacity measurement method

- By congestion (saturated conditions only)
- By total departures from queue (unsaturated conditions)
Measuring capacity: unsaturated gap cycles

\[ s = \frac{3600}{\beta} \]

Capacity = \( s \frac{g}{c} \)

Unused capacity

Unsaturated flow

Saturated flow

Queued vehicles

Entry stream vehicles

Give-way (yield) / stop line

Vehicle arrivals

Queue

Back of queue

Opposing stream vehicles

We know traffic
"g / c" ratio

Captivity = \frac{s (g/c)}{\text{Opposing flow rate (pcu/h)}}

Two-lane sign control
Critical gap = 4 s
Follow-up headway = 2 s

where
s = \frac{3600}{\beta}
Issue: Linear regression (UK) vs Gap acceptance (US & Australia)

- “Empirical” misnomer (use “regression”)
- HCM 97 Chapter 10 on Roundabouts: GAP-ACCEPTANCE METHOD
- UK method for 2-way stop-sign control is also a REGRESSION MODEL (HCM and aaSIDRA use GAP ACCEPTANCE)

!!! Same issues arise !!!
Issue: Linear regression (UK) vs Gap acceptance (US & Australia)

Roundabout Geometry:
Compared with the aaSIDRA model, the TRL regression model is OVERSENSITIVE to:

- inscribed diameter
- approach (lane) width
- and other geometric variables.

This is probably because the TRL database used in 1980s included a large number of sub-standard roundabout designs that existed in the UK historically. This makes the UK model not readily applicable to other countries where modern roundabouts are used.
Issue: Linear regression (UK) vs Gap acceptance (US & Australia)

Roundabout Geometry:
Modern roundabout designs are more uniform, and therefore, the more recent models based on them are less sensitive to the geometric variables (as in the case of the Australian roundabout model used in aaSIDRA).

German linear regression and gap-acceptance models were found to be sensitive only to the number of entry and circulating lanes!
Issue: Linear regression (UK) vs Gap acceptance (US & Australia)

Linearity could be due to measurement method (by approach rather than lane by lane)

A demonstration using aaSIDRA follows >>
(similar exercise using real-life & simulation data recommended)
Capacity models: Linear or Non-linear?

LANE capacities appear non-linear

\[ y = 1635.8e^{-0.0009x} \]
\[ R^2 = 0.8019 \]

\[ y = 0.0002x^2 - 1.0175x + 1529.2 \]
\[ R^2 = 0.8073 \]
Capacity models: Linear or Non-linear? APPROACH capacities appear linear but exponential (non-linear) appears to be better.

\[ y = 2520.8e^{-0.0007x} \]
\[ R^2 = 0.491 \]

\[ y = 0.0001x^2 - 1.0848x + 2413.7 \]
\[ R^2 = 0.3853 \]

\[ y = -0.7769x + 2284.3 \]
\[ R^2 = 0.3781 \]
A demonstration of regression vs
mathematical model:
capacity of cylindrical containers

\[ V = \pi h D^2 / 4 \]
h, D parameters generated randomly (200 data points)
Regression on h & D << the “empirical” approach

- $y = 2.5759x$
  - $R^2 = 0.1715$

- $y = 0.0454x^2 - 0.4079x$
  - $R^2 = 0.6126$

- $y = 3.0845x$
  - $R^2 = 0.5091$
Mathematical model: SIDRA approach

\[ C = h \ A \]

where \( A = \prod (D/2)^2 \)

is the base area
**aaSIDRA performance model for intersections**

(more general form of the HCM two-term delay models)

\[ P = P_1 + P_2 \]

<table>
<thead>
<tr>
<th>Performance measure</th>
<th>( P_1 )</th>
<th>( P_2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delay</td>
<td>( P_1 )</td>
<td>( P_2 )</td>
</tr>
<tr>
<td>Queue length</td>
<td>( P_1 )</td>
<td>( P_2 )</td>
</tr>
<tr>
<td>Effective stop rate</td>
<td>( P_1 )</td>
<td>( P_2 )</td>
</tr>
<tr>
<td>Queue clearance time</td>
<td>( P_1 )</td>
<td>NA</td>
</tr>
<tr>
<td>Proportion queued</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Queue move-up rate</td>
<td>NA</td>
<td>( P_2 )</td>
</tr>
</tbody>
</table>
Why gap acceptance model?

Gap-acceptance model is needed to estimate performance statistics (not just CAPACITY)
Issue: Cycle-average queue vs average back of queue

Unsaturated cycle: $T_2 < T_3$
Issue: Need for delay model comparisons

HCM 94/97

\[ y = 0.5486x + 6.6815 \]
\[ R^2 = 0.4186 \]

aaSIDRA

\[ y = 0.6343x + 3.4477 \]
\[ R^2 = 0.6581 \]
Issue: Modeling of flares / short lanes

- Short lane capacity is flow dependent
- aaSIDRA model uses back of queue and predicts excess flow into adjacent lane
Issue: Lane utilisation

Lane under-utilisation is best modeled using a lane-by-lane method as in aaSIDRA.

This helps with design of lane disciplines.
Roundabout case: Melbourne

ITE 67th Ann. Meeting

We know traffic
Roundabout case: Canberra

See ARR 321
About Australia

Australia compared with United States

6 cars per 10 people
29 miles of road per 1000 people

Australia
2,974,584 sq. miles

9 cars per 10 people
16 miles of road per 1000 people

United States
2,974,726 sq. miles
aaSIDRA

aaTraffic Signalised & unsignalised Intersection
Design and Research Aid

Further info available from
“it is still an unending story”