6.4.2 Capacity of Two-Way Intersections-HCM Method

For further details see HCM 2000 chapter 17.

Capacity analysis at two-way stop-controlled (TWSC) intersections depends on a clear description and understanding of the interaction of drivers on the minor or stop-controlled approach with drivers on the major street. Both gap acceptance and empirical models have been developed to describe this interaction. Procedures described in this section rely on a gap acceptance model developed and refined in Germany. This model starts with calculation of the conflicting traffic for minor-street movements; as follows.

CONFLICTING TRAFFIC

Each movement at a TWSC intersection faces a different set of conflicts that are directly related to the nature of the movement. These conflicts are shown in the following table, which illustrates the computation of the parameter $v_{c,x}$, the conflicting flow rate for movement $x$, that is, the total flow rate that conflicts with movement $x$ (veh/h).

The table also identifies the conflicting flow rates for each stage of a two-stage gap acceptance process that takes place at some intersections where vehicles store in the median area. If a two-stage gap acceptance process is not present, the conflicting flow rates shown in the rows labeled Stage I and Stage II should be added together and considered as one conflicting flow rate for the movement in question.
Table: Definition And Computation of Conflicting Flows

<table>
<thead>
<tr>
<th>Subject Movement</th>
<th>Subject and Conflicting Movements</th>
<th>Conflicting Traffic Flows, $v_{c,i}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major LT (1, 4)</td>
<td><img src="image1" alt="Diagram" /></td>
<td>$v_{c,1} = v_5 + v_8[a] + v_{16}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minor RT (9, 12)</td>
<td><img src="image2" alt="Diagram" /></td>
<td>$v_{c,9} = \frac{v_5}{N} + 0.5v_2[c] + v_{14} + v_{15}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$v_{c,12} = \frac{v_5}{N} + 0.5v_2[c] + v_{14} + v_{15}$</td>
</tr>
<tr>
<td>Stage I</td>
<td><img src="image3" alt="Diagram" /></td>
<td>$v_{c,16} = 2v_1 + v_2 + 0.5v_3[c] + v_{15}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minor TH (8, 11)</td>
<td><img src="image4" alt="Diagram" /></td>
<td>$v_{c,18} = 2v_1 + v_2 + 0.5v_3[c] + v_{15}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage II</td>
<td><img src="image5" alt="Diagram" /></td>
<td>$v_{c,16} = 2v_4 + v_5 + v_6[a] + v_{16}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minor LT (7, 10)</td>
<td><img src="image6" alt="Diagram" /></td>
<td>$v_{c,17} = 2v_4 + v_5 + 0.5v_3[c] + v_{15}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage II</td>
<td><img src="image7" alt="Diagram" /></td>
<td>$v_{c,16} = 2v_4 + v_5 + 0.5v_3[c] + v_{15}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><img src="image8" alt="Diagram" /></td>
<td>$v_{c,16} = 2v_4 + v_5 + 0.5v_3[c] + v_{15}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Highways and Transportation I, ECIV 4333, Lecture Notes 2007
Instructors: Dr. Yahya Sarraj and Dr. Essam Almasri
The following notes apply to the previous table:

a. If right-turning traffic from the major street is separated by a triangular island and has to comply with a yield or stop sign, $v_6$ and $v_3$ need not be considered.

b. If there is more than one lane on the major street, the flow rates in the right lane are assumed to be $v_2/N$ or $v_5/N$, where $N$ is the number of through lanes. The user can specify a different lane distribution if field data are available.

c. If there is a right-turn lane on the major street, $v_3$ or $v_6$ should not be considered.

d. Omit the farthest right-turn $v_3$ for Subject Movement 10 or $v_6$ for Subject Movement 7 if the major street is multilane.

e. If right-turning traffic from the minor street is separated by a triangular island and has to comply with a yield or stop sign, $v_9$ and $v_{12}$ need not be considered.

f. Omit $v_9$ and $v_{12}$ for multilane sites, or use one-half their values if the minor approach is flared.

CRITICAL GAP AND FOLLOW-UP TIME

The critical gap, $t_c$, is defined as the minimum time interval in the major-street traffic stream that allows intersection entry for one minor-street vehicle. Thus, the driver's critical gap is the minimum gap that would be acceptable. A particular driver would reject any gaps less than the critical gap and would accept gaps greater than or equal to the critical gap. Estimates of critical gap can be made on the basis of observations of the largest rejected and smallest accepted gap for a given intersection.

The time between the departure of one vehicle from the minor street and the departure of the next vehicle using the same major-street gap, under a condition of continuous queuing on the minor street, is called the follow-up time, $t_f$. Thus, $t_f$ is the headway that defines the saturation flow rate for the approach if there were no conflicting vehicles on movements of higher rank.

Base values of $t_c$ and $t_f$ for passenger cars are given in the next table. The values are based on studies throughout the United States and are representative of a broad range of conditions. Base values of $t_c$ and $t_f$ for a six-lane major street are assumed to be the same as those for a four-lane major street. Adjustments are made to account for the presence of heavy vehicles, approach grade, T-intersections, and two-stage gap acceptance. The critical gap is computed separately for each minor movement by this equation.
\[
t_{c,x} = t_{c,\text{base}} + t_{c,HV} P_{HV} + t_{c,G} G - t_{c,T} - t_{3,LT}
\]

where

- \( t_{c,x} \) = critical gap for movement x (s),
- \( t_{c,\text{base}} \) = base critical gap from Exhibit 17-5 (s),
- \( t_{c,HV} \) = adjustment factor for heavy vehicles (1.0 for two-lane major streets and 2.0 for four-lane major streets) (s),
- \( P_{HV} \) = proportion of heavy vehicles for minor movement,
- \( t_{c,G} \) = adjustment factor for grade (0.1 for Movements 9 and 12 and 0.2 for Movements 7, 8, 10, and 11) (s),
- \( G \) = percent grade divided by 100,
- \( t_{c,T} \) = adjustment factor for each part of a two-stage gap acceptance process, (1.0 for first or second stage; 0.0 if only one stage) (s), and
- \( t_{3,LT} \) = adjustment factor for intersection geometry (0.7 for minor-street left-turn movement at three-leg intersection; 0.0 otherwise) (s).

**Table: Base Critical Gaps And Follow-Up Times For Twsc Intersections**

<table>
<thead>
<tr>
<th>Vehicle Movement</th>
<th>Base Critical Gap, ( t_{c,\text{base}} ) (s)</th>
<th>Base Follow-Up Time, ( t_{f,\text{base}} ) (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Two-Lane Major Street</td>
<td>Four-Lane Major Street</td>
</tr>
<tr>
<td>Left turn from major</td>
<td>4.1</td>
<td>4.1</td>
</tr>
<tr>
<td>Right turn from minor</td>
<td>6.2</td>
<td>6.9</td>
</tr>
<tr>
<td>Through traffic on minor</td>
<td>6.5</td>
<td>6.5</td>
</tr>
<tr>
<td>Left turn from minor</td>
<td>7.1</td>
<td>7.5</td>
</tr>
</tbody>
</table>

The follow-up time is computed for each minor movement using next equation. Adjustments are made for the presence of heavy vehicles.

\[
t_{f,x} = t_{f,\text{base}} + t_{f,HV} P_{HV}
\]

where

- \( t_{f,x} \) = follow-up time for minor movement x (s),
- \( t_{f,\text{base}} \) = base follow-up time from Exhibit 17-5 (s), and
- \( t_{f,HV} \) = adjustment factor for heavy vehicles (0.9 for two-lane major streets and 1.0 for four-lane major streets), and
- \( P_{HV} \) = proportion of heavy vehicles for minor movement.
Values from the previous table are considered typical. If smaller values for \( t_c \) and \( t_f \) are observed, capacity will be increased. If larger values for \( t_c \) and \( t_f \) are used, capacity will be decreased. (The relationship between the potential capacity and \( t_c \) or \( t_f \) is inverse)

**POTENTIAL CAPACITY**

The gap acceptance model used in this method computes the potential capacity of each minor traffic stream in accordance with this equation:

\[
C_{p,x} = \nu_{c,x} \frac{e^{-\nu_{c,x} t_{c,x} / 3600}}{1 - e^{-\nu_{c,x} t_{f,x} / 3600}}
\]

Where

- \( c_{p,x} \) = potential capacity of minor movement \( x \) (veh/h),
- \( \nu_{c,x} \) = conflicting flow rate for movement \( x \) (veh/h),
- \( t_{c,x} \) = critical gap (i.e., the minimum time that allows intersection entry for one minor-stream vehicle) for minor movement \( x \) (s), and
- \( t_{f,x} \) = follow-up time (i.e., the time between the departure of one vehicle from the minor street and the departure of the next under a continuous queue condition) for minor movement \( x \) (s).

**6.4.3 Capacity of T-Intersections Using British Method**

*For further details refer to O’Flaherty 97 page 364.*

The capacity of a priority T-intersection is primarily dependent upon:

- The ratio of the flows on the major and minor roads;
- The critical (minimum) gap in the main road traffic stream acceptable to entering traffic; and
- The maximum delay acceptable to minor road vehicles.

Empirical research has resulted in predictive capacity equations for T-intersections which where derived from traffic flow measurements and from certain broad features of junction layout. This empirical approach has been adopted by the department of transport in Britain.
A T-intersection has six separate traffic streams (shown in the next figure), of which:

- The through streams on the major road (C-A and B-C) and the right-turn stream off the major road (A-B) are generally assumed to be priority streams and to suffer no delays from other traffic;
- While the two minor road streams (B-A and B-C) and the major road left-turn stream (C-B) incur delays due to their need to give way to higher priority streams.

The predictive capacity equations for the three non-priority streams are as follows:

\[
q'_{B-A} = D\{627 + 14 \, W_{CR} - Y[0.364 \, q_{A-C} + 0.114 \, q_{A-B} + 0.229 \, q_{C-A} + 0.520 \, q_{C-B}]\}
\]
\[
q'_{B-C} = E\{745 - Y[0.364 \, q_{A-C} + 0.114 \, q_{A-B}]\}
\]
\[
q'_{C-B} = F\{745 - 0.364 \, Y[q_{A-C} + q_{A-B}]\}
\]

where

\[
Y = [1 - 0.0345 W]
\]
\[
D = [1+0.094(W_{B-A} - 3.65)] \, [1+0.0009(V_{l B-A} - 120)] \, [1+0.0006(V_{r B-A} - 150)]
\]
\[
E = [1+0.094(W_{B-C} - 3.65)] \, [1+0.0009(V_{r B-C} - 120)]
\]
\[
F = [1+0.094(W_{C-B} - 3.65)] \, [1+0.0009(V_{l C-B} - 120)]
\]

Where

\(W_{B-A}\) and \(W_{B-C}\) = the average widths of each of the minor road approach lanes for waiting vehicles in streams B-A and B-C, respectively, measured over a distance of 20 m upstream from the give Way line (2.05 – 4.70 m).
Consider the following remarks when applying the mentioned method:
- All capacities and flows are in passenger car units per hour (pcu/h), and distances are in meters;
- Capacities are always positive or zero, if the right-hand side of any equation is negative, the capacity is taken as zero;
- The ranges within which the geometric data are considered valid are:
  - $W = 2.05 - 4.70$ m,
  - $V_r = 22-250$ m,
  - $V_l = 17-250$ m,
  - $W_{CR} = 1.2-9$ m (dual carriageway sites only),
  - $W' = 6.4 - 20$ m

### 6.5 Roundabouts

O’Flaherty 97 page 369, O’Flaherty 86 page 350

Old type was called conventional roundabout

There are 3 types of roundabout:

1. **Normal roundabout**
   - It has a one-way circulating carriageway around a kerbed central island. The entries may or may not have flared approaches. (Preferred to be flared)
   - In Britain the central island is normally 4m or more in diameter and the entries are flared.