Chapter 7
Road Intersection Design

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An intersection is an area, shared by two or more roads, whose main function is to provide for the change of route directions.

Intersections vary in complexity from:

- **simple intersection**: has only two roads crossing at a right angle
- **complex intersection**: three or more roads cross within the same area.
Drivers therefore have to make a decision at an intersection concerning which of the alternative routes they wish to take.

Intersections tend to have a high potential for crashes.
Intersection Design

- The **overall traffic flow** on any highway depends to a great extent on the **performance of the intersections**, since intersections usually operate at a **lower capacity** than through sections of the road.
Intersection Design

Intersections are classified into three general categories:

- grade-separated without ramps,
- grade-separated with ramps (commonly known as interchanges),
- and at-grade.
Basic forms of intersections

T

Y

Scissors

Cross

Staggered

Staggered and skewed

multiway
Figure 7.1 shows different types of grade separated intersections,
Figure 7.1 Examples of Grade Separated Interchanges
Intersection Design

Figure 7.1 Examples of Grade Separated Interchanges
Intersection Design

Examples of Grade Separated Interchanges
Intersection Design

Examples of Grade Separated Interchanges
Figures 7.2 and 7.3 show different types of at-grade intersections.

This Chapter presents the basic principles of the design of at-grade intersections.
Figure 7.2 Examples of At-Grade Intersections
Intersection Design

(a) Raised Islands on a Three-Leg Intersection

Figure 7.3 Examples of At-Grade Intersections in Urban Areas
(b) A Four-Leg Intersection

Figure 7.3 Examples of At-Grade Intersections in Urban Areas
Intersection Design

Figure 7.3 Examples of At-Grade Intersections in Urban Areas

(c) A Y-Intersection
7.1 TYPES OF AT-GRADE INTERSECTIONS

- The basic types of at-grade intersections are *T* or three-leg intersections which consist of three approaches;
- four-leg or cross intersections, which consist of four approaches;
- and multi-leg intersections, which consist of five or more approaches.
7.1.1 T Intersections

- Figure 7.4 on page 270 shows different types of T intersections
- Simplest shown in Figure 7.4a
- Channelized one with divisional islands and turning roadways shown in Figure 7.4d.
Figure 7.4 Examples of T Intersections

(a) Plain ‘T’ Intersection

(b) ‘T’ Intersection (With Right Turn Lane)
Figure 7.4 Examples of T Intersections
7.1.1 T Intersections

Channelization involves the provision of facilities such as pavement markings and traffic islands to regulate and direct conflicting traffic streams into specific travel paths.
7.1.1 T Intersections

- The intersection shown in Figure 7.4a is suitable for minor or local roads and may be used when minor roads intersect important highways with an intersection angle less than 30 degrees from the normal.

- Also suitable for use in rural two-lane highways that carry light traffic.
Figure 7.4 Examples of T Intersections

(a) Plain ‘T’ Intersection

(b) ‘T’ Intersection (With Right Turn Lane)
7.1.1 T Intersections

- At locations with higher speeds and turning volumes, which increase the potential of rear-end collisions between through vehicles and turning vehicles.

- Usually an additional area of surfacing or flaring is provided, as shown in Figure 7.4b.
7.1.1 T Intersections

- the **flare** is provided to **separate right-turning** vehicles from through vehicles approaching from the east.
7.1.1 T Intersections

In cases where left-turn volume from a through road onto a minor road is sufficiently high but does not require a separate left-turn lane, an auxiliary lane may be provided, as shown in Figure 7.4c.
Figure 7.4 Examples of T Intersections

(c) ‘T’ Intersection (With Right-Hand Passing Lane)

(d) ‘T’ Intersection (With Divisional Island and Turning Roadways)
7.1.1 T Intersections

Figure 7.4d shows a channelized T intersection in which the two-lane through road has been converted into a divided highway through the intersection.

Intersection of this type probably will be signalized.
7.1.2 Four-Leg Intersections

- Figure 7.5 shows varying levels of channelization at a four-leg intersection.

- unchannelized intersection shown in Figure 7.5a on page 272 is used mainly at locations where minor or local roads cross.
Figure 7.5 Examples of Four-Leg Intersections
Intersection Design

7.1.2 Four-Leg Intersections

- It also can be used where a minor road crosses a major highway.
- In these cases, the turning volumes are usually low and the roads intersect at an angle that is not greater than 30 degrees from the normal.
7.1.2 Four-Leg Intersections

- When right-turning movements are frequent, right-turning roadways, such as those in Figure 7.5b, can be provided.
- Also common where pedestrians are present.
Intersection Design

Figure 7.5 Examples of Four-Leg Intersections
7.1.2 Four-Leg Intersections

- The layout shown in Figure 7.5c is suitable for:
  - a two lane highway that is
  - not a minor crossroad and that
  - carries moderate volumes at
  - high speeds or
  - operates near capacity.
Intersection Design

Figure 7.5 Examples of Four-Leg Intersections
7.1.2 Four-Leg Intersections

- Figure 7.5d shows a suitable design for four-lane approaches:
  - carrying high through volumes and
  - high turning volumes.
- This type of intersection is usually signalized.
Intersection Design

Figure 7.5 Examples of Four-Leg Intersections
7.1.3 Multi-leg Intersections

- Multi-leg intersections have five or more approaches.
- Figure 7.6
- Whenever possible, this type of intersection should be avoided.
Intersection Design

Figure 7.6 Examples of Multileg Intersections
7.1.3 Multileg Intersections

In order to:

- remove some of the conflicting movements and
- increase safety and operation,

one or more of the legs are realigned.

Figure 7.6a, the diagonal leg of the intersection is realigned.
7.1.3 Multileg Intersections

- This results in the formation of an additional T intersection
- but with the multileg intersection now converted to a four-leg intersection.
- Two important factors to consider:
  - The diagonal road should be realigned to the minor road
  - The distance between the intersections
7.1.3 Multileg Intersections

- realignment of a six-leg intersection
- Figure 7.6b, forming two four-leg intersections.
- realignment to be made to the minor road.
- forming two additional T intersections and resulting in a total of three intersections.
Intersection Design

Figure 7.6 Examples of Multileg Intersections
7.1.3 Multileg Intersections

- the distances between these intersections should be great enough to allow for the independent operation of each intersection.
Intersection Design

Roundabouts

GET AROUND SAFELY

[Roundabout Diagram]

[Roundabout Signage]
7.1.4 Traffic Circles

A traffic circle is a circular intersection that provides a circular traffic pattern with significant reduction in the crossing conflict points.
7.1.4 Traffic Circles

- The Federal Highway Administration publication, *Roundabouts: An Informational Guide*, describes three types of traffic circles:
  1. rotaries,
  2. neighborhood traffic circles, and
  3. roundabouts.
NCHRP
REPORT 672

Roundabouts:
An Informational Guide
Second Edition

In Cooperation with
U.S. Department of Transportation
Federal Highway Administration
7.1.4 Traffic Circles

1. *Rotaries* have large diameters that are usually greater than 100m (300 ft), thereby allowing speeds exceeding 45km/h (30 mi/h), with a minimum horizontal deflection of the path of the through traffic.
7.1.4 Traffic Circles

2. *Neighborhood traffic circles* have diameters that are much smaller than rotaries and therefore allow much lower speeds.

- Consequently, they are used mainly at the intersections of local streets,
- traffic calming aesthetic device.
- they consist of pavement markings and do not usually employ raised Islands.
7.1.4 Traffic Circles

3. **Roundabouts** have specific defining characteristics that separate them from other circular intersections. These include:

- **Yield control** at each approach
- **Separation of conflicting traffic** movements by pavement markings or raised islands
- Geometric characteristics of the central island that typically allow travel **speeds of less than 30 mi/h**
- **Parking not usually allowed** within the circulating roadway.
7.1.4 Traffic Circles

- Figure 7.7a shows the geometric elements of a single-lane modern roundabout,

- Figure 7.7b shows a photograph of an existing roundabout.
Intersection Design

Figure 7.7 Geometric Elements and Example of Roundabout

(a) Geometric Elements of a Single-Lane Modern Roundabout
Intersection Design

Figure 7.7 Geometric Elements and Example of Roundabout
7.1.4 Traffic Circles

Roundabouts can be further categorized into six classes based on the size and environment in which they are located.

1. Mini roundabouts
2. Urban compact roundabouts
3. Urban single-lane roundabouts
4. Urban double-lane roundabouts
5. Rural single-lane roundabouts
6. Rural double-lane roundabouts
Mini Roundabout
### Table 7.1 Characteristics of Roundabout Categories

<table>
<thead>
<tr>
<th>Design Element</th>
<th>Mini-Roundabout</th>
<th>Urban Compact</th>
<th>Urban Single-Lane</th>
<th>Urban Double-Lane</th>
<th>Rural Single-Lane</th>
<th>Rural Double-Lane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommended maximum entry speed</td>
<td>25 km/h (15 mi/h)</td>
<td>25 km/h (15 mi/h)</td>
<td>35 km/h (20 mi/h)</td>
<td>40 km/h (25 mi/h)</td>
<td>40 km/h (25 mi/h)</td>
<td>50 km/h (30 mi/h)</td>
</tr>
<tr>
<td>Maximum number of entering lanes per approach</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Typical inscribed circle diameter</td>
<td>13 to 25 m (45 ft to 80 ft)</td>
<td>25 to 30 m (80 to 100 ft)</td>
<td>30 to 40 m (100 to 130 ft)</td>
<td>45 to 55 m (150 to 180 ft)</td>
<td>35 to 40 m (115 to 130 ft)</td>
<td>55 to 60 m (180 to 200 ft)</td>
</tr>
<tr>
<td>Splitter island treatment</td>
<td>Raised if possible, crosswalk cut if raised</td>
<td>Raised, with crosswalk cut</td>
<td>Raised, with crosswalk cut</td>
<td>Raised, with crosswalk cut</td>
<td>Raised and extended, with crosswalk cut</td>
<td>Raised and extended, with crosswalk cut</td>
</tr>
<tr>
<td>Typical daily service volumes on four-leg roundabout (veh/day)</td>
<td>10,000</td>
<td>15,000</td>
<td>20,000</td>
<td>Refer to the source</td>
<td>20,000</td>
<td>Refer to the source</td>
</tr>
</tbody>
</table>

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1 Assumes 90° entries and no more than four legs.

8.2 CONFLICT POINTS AT INTERSECTIONS
Intersection Control

This figure will be explained later in detail.
8.2 CONFLICT POINTS AT INTERSECTIONS

Conflicts occur when traffic streams moving in different directions interfere with each other.

Three types of conflicts:
- merging,
- diverging,
- crossing.
The number of possible conflict points at any intersection depends on:
- the number of approaches,
- the turning movements, and
- the type of traffic control at the intersection.
Intersection Control

- Crossing conflicts, however, tend to have the most severe effect on traffic flow and should be reduced to a minimum whenever possible.
8.2 CONFLICT POINTS AT INTERSECTIONS

- Figure 8.3 four-approach unsignalized intersection.

- There are 32 conflict points in this case.
Figure 8.3 Conflict Points at a Four-Approach Unsignalized Intersection
Conflict points at a T-Intersection
9 conflict points:
3 crossing
3 merging
3 diverging
Conflict Points at a + & O Intersection

- 16 Crossing
- 8 Diverging
- 8 Converging

- 0 Crossing
- 4 Diverging
- 4 Converging
Conflict Points Exercise

- Examine the change in the number of conflict points at a four arm road intersection in the following cases:
  - Converting the intersection into 3-arms instead of 4-arms
  - Preventing left-turning movements
  - Converting one road to one-way
Intersection Control

Priority Intersections
Intersection Control

Types of Intersection Control

- Priority control
- Roundabout
- Traffic signals

The choice of the type of control depends on:

• The type of intersection
• Traffic volume in each conflicting stream

See the MUTCD for details
All drivers on approaches with yield signs should **slow down** and **give the right of way** to all conflicting vehicles at the intersection.
An approaching vehicle **must stop** before entering the intersection.

Stop sign should be used **only when it is warranted**. Used at locations with high speed, restricted view and serious crashes.
Multi-way Stop Signs

They require that **all vehicles stop** before entering the intersection.

Used at **low volume** intersections and when traffic volumes on all approaches are approximately equal.
Two-way Stop Signs

They require that vehicles on the minor road must stop before entering the intersection.

Used on a major-minor road intersection.
6.4 Priority Intersections

Two-way Stop Signs
6.4 Priority Intersections

Two-way Stop Signs
Intersection Design

Capacity of TWSC Intersections

HCM Method
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:
6.4 Priority Intersections

6.4.1 Capacity of Two-Way Intersections - HCM Method

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,

$$v_{c,x} = \text{the total flow rate that conflicts with movement } x \text{ (veh/h)}.$$
6.4 Priority Intersections

6.4.1 Capacity of Two-Way Intersections - HCM Method

CONFLICTING TRAFFIC
One stage and two stage:

Two-Stage Process

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 present, the conflicting flow rates shown in the rows labeled Stage I and Stage II should be determined for the movement in question.

The potential capacity will be calculated for each stage.

The minimum value of capacity will be considered.
6.4 Priority Intersections

6.4.1 Capacity of Two-Way Intersections - HCM Method

One-stage Process:

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.
Numbering System

HCM Numbering system for traffic & pedestrian movements at road intersections
The gap acceptance model used in this method computes the potential capacity of each minor traffic stream in accordance with this equation:

\[
P_{p,x} = \frac{V_{c,x}}{1 - e^{-V_{c,x}t_{c,x}/3600}}
\]

Where

- \(c_{p,x}\) = potential capacity of minor movement x (veh/h),
- \(v_{c,x}\) = 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).
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.
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.
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.
Minor TH (8, 11)

Stage I

\[ v_{c,I,8} = 2v_1 + v_2 + 0.5v_3^{[c]} + v_{15} \]

Stage II

\[ v_{c,II,8} = 2v_4 + v_5 + v_6^{[a]} + v_{16} \]
\[
\begin{align*}
\nu_{c,1.7} &= 2\nu_1 + \nu_2 + 0.5\nu_3^{[c]} + \nu_{15} \\
\nu_{c,11.7} &= 2\nu_4 + \frac{\nu_5}{N} + 0.5\nu_6^{[d]} + 0.5\nu_{12}^{[e,f]} + 0.5\nu_{11} + \nu_{13} \\
\nu_{c,11.10} &= 2\nu_1 + \frac{\nu_2}{N} + 0.5\nu_3^{[d]} + 0.5\nu_9^{[e,f]} + 0.5\nu_8 + \nu_{14} \\
\nu_{c,11.10} &= 2\nu_4 + \nu_5 + 0.5\nu_6^{[c]} + \nu_{16}
\end{align*}
\]
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 (tc)
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 (5). A particular driver would reject any gaps less than the critical gap.

FOLLOW-UP TIME ($t_f$)
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, $t_f$. $t_f$ is the headway that defines the saturation flow rate for the approach if there were no conflicting vehicles on movements of higher rank.
6.4 Priority Intersections

CRITICAL GAP

Base values of $t_c$ and $t_f$ for passenger cars are given in next Table.
The values are based on studies throughout the United States.

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.

$$t_{c,x} = t_{c,base} + t_{c,HV} P_{HV} + t_{c,G} G - t_{c,T} - t_{3,LT}$$
CRITICAL GAP

\[ t_{c,x} = t_{c,\text{base}} + t_{c,HV} P_{HV} + t_{c,G} G - t_{c,T} - t_{3,LT} \]

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,
6.4 Priority Intersections

CRITICAL GAP

\[ t_{c,x} = t_{c,\text{base}} + t_{c,\text{HV}} P_{HV} + t_{c,G} G - t_{c,T} - t_{3,LT} \]

\( t_{c,T} \) = 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>
<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>
6.4 Priority Intersections

FOLLOW-UP TIME

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),
- \( t_{f,HV} \) 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.
6.4 Priority Intersections

EXAMPLES
Problem 1

A cross-road intersection is controlled by priority rule. The percent of truck 10%, the grade is 4%. The demand flow in the design year is shown in (Fig 1).

Find the capacity of movements 1, 7, 8, 9. and then find RFC (Ratio of flow to capacity) & Comment.

(Assume one stage)

Fig (1)
Solution:

1) 

\[ V_{C,1} = V_5 + V_6^{[a]} + V_{16} \]

\[ = (700 + 700) + 0^{\text{neg}} + 0 = 1400 \]

\[ t_{C,1} = t_{C,\text{base}} + t_{C,\text{HV}} \times P_{HV} + t_{C,G} \times G - t_{C,T} - T_{3,LT} \]

\[ = 4.1 + 2.0 \times 0.1 + 0.0 \times \left( \frac{4}{100} \right) - 0.0 - 0.0 = 4.3 \]

\[ t_{f,.1} = t_{f,\text{base}} + t_{f,\text{HV}} \times P_{HV} \]

\[ = 2.2 + 1.0 \times 0.1 = 2.3 \]

\[ C_{P,1} = V_{C,1} \times \frac{-V_{C,1} \times t_{C,1}}{3600} = 444.8 \]

\[ RFC = \frac{80}{445} = 0.18 < 0.85 \quad \text{Good Design} \]
Solution:

7) 

\[ V_{C,71} = 2V_1 + V_2 + 0.5V_3^c + V_{15} \]

\[ = 2 \times 80 + (500 + 500) + 0^{neg} + 0 = 1160 \]

\[ V_{C,7II} = 2V_4 + \frac{V_5}{N} + 0.5V_6^d + 0.5V_{12}^{e,f} + 0.5V_{11} + V_{13} \]

\[ = 2 \times 120 + 700 + 0^{neg} + 0^{neg} + 0.5(120) + 0 = 1000 \]

Assuming one stage

\[ V_{C,7} = 1160 + 1000 = 2160 \text{ veh/h} \]

\[ t_{C,7} = t_{C,base} + t_{C,HV} \times P_{HV} + t_{C,G} \times G - t_{C,T} - T_{3,LT} \]

\[ = 7.5 + 2.0 \times 0.1 + 0.2 \times \left( \frac{4}{100} \right) - 0.0 - 0.0 = 7.708 \]

\[ t_{f,7} = t_{f,base} + t_{f,HV} \times P_{HV} \]

\[ = 3.5 + 1.0 \times 0.1 = 3.6 \]

\[ C_{P,7} = V_{C,7} \times \frac{e^{-V_{C,7} \times t_{C,7}}}{3600} = 23.9 \]

\[ RFC = \frac{20}{23.9} = 0.84 < 0.85 \text{ Good Design} \]
Problem 2

A cross-road intersection is controlled by priority rule. The percent of truck 10%, the grade is 4%. The demand flow in the design year is shown in (Fig 1).

Find the capacity of movements 7, 8, 10 and 11.

Then find RFC (Ratio of flow to capacity) & Comment.

(Assume two stage)
Capacity of T- Intersection using the British Method
6.4 Priority Intersections

6.4.3 Capacity of T-Intersections Using British Method

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.
6.4 Priority Intersections

6.4.3 Capacity of T-Intersections Using British Method

A T-intersection has six separate traffic stream (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.
6.4 Priority Intersections

6.4.3 Capacity of T-Intersections Using British Method

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

\[ q_{B-A}^s = D\{627 + 14 W_{CR} - Y[0.364 q_{A-C} + 0.114 q_{A-B} + 0.229 q_{C-A} + 0.520 q_{C-B}]\} \]

\[ q_{B-C}^s = E\{745 - Y[0.364 q_{A-C} + 0.114 q_{A-B}]\} \]

\[ q_{C-B}^s = F\{745 - 0.364 Y[q_{A-C} + q_{A-B}]\} \]

where

\[ Y = [1 - 0.0345W] \]

\[ D = [1+0.094(W_{B-A} - 3.65)] [1+0.0009(V_{lB-A} - 120)] [1+.0006(V_{rB-A} - 150)] \]

\[ E = [1+0.094(W_{B-C} - 3.65)] [1+0.0009(V_{lB-C} - 120)] \]

\[ F = [1+0.094(W_{C-B} - 3.65)] [1+0.0009(V_{lC-B} - 120)] \]

\[ W_{CR} = \] is the average width of the central reserve lane, at the intersection, on a dual carriageway road.
\[ Y = [1 - 0.0345W] \]
\[ D = [1 + 0.094(W_{B-A} - 3.65)] [1 + 0.0009(V_{r-B-A} - 120)] [1 + 0.0006(V_{r-B-A} - 150)] \]
\[ E = [1 + 0.094(W_{B-C} - 3.65)] [1 + 0.0009(V_{l-B-C} - 120)] \]
\[ F = [1 + 0.094(W_{C-B} - 3.65)] [1 + 0.0009(V_{l-C-B} - 120)] \]

\( W_{B-A} \) 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).

\( W_{C-B} \) = the average width of the left-turn (central) lane on the major road, or 2.1 m if there is no explicit provision for left turners in stream C-B (2.05 – 4.70 m).

\( V_{l-B-A} \), \( V_{r-B-A} \) and \( V_{l-B-C} \) = the left and right visibility distances, available from the minor road (22 - 250 m).

\( V_{l-C-B} \) = the visibility available to left-turning vehicles waiting to turn left from the major road (22 - 250 m).

\( W \) = the average major road carriageway width at the intersection; in the case of dual carriageways and single carriageways with ghost or raised islands, \( W \) excludes the width of the central (turning) lane.
6.4.3 Capacity of T-Intersections Using British Method

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
APPENDIX B
MEASUREMENT OF GEOMETRIC PARAMETERS AFFECTING
CAPACITY

These are shown for 3-arm junctions. The corresponding measurements for
4-arm junctions are made in the same way.

i) Lane width for non-priority streams
   \((w_B-C, w_B-A\) and \(w_C-B)\)

Where there are clear lane markings the width is measured directly. The
average of measurements taken at 5m intervals over a distance of 20m
upstream from the give-way point is used. Any measurement exceeding 5m
is reduced to 5m before the average is taken.

Where the lane markings are unclear or absent, the diagrams in Figure B1
are used, and the lane width \(w\) calculated according to:

\[
    w = \frac{(a + b + c + d + e)}{5} \text{ metres}
\]

For the left turn lane from the major road, the measurements shown in
Figure B2 are used, again taking an average width over 20 metres up to the
give-way point.
ii) Major road width (W) and central reserve width (WCR)

The four parts of Figure B3 show the main components of major road width. They are combined to give:

a) the total carriageway width is

\[ W = \frac{(W1 + W2 + W3 + W4)}{2} \]

b) the width of the central reserve at dual-carriageway sites with kerbed central reserve is

\[ WCR = \frac{(W5 + W6)}{2} \]

Where a layout has metre strips (or any hatching) alongside the kerbs, the carriageway width should exclude the metre strips or hatching width, and the central reserve width should include any metre strips or hatching width around the kerbed central island.
Lane width measurements for the right-turning minor road stream ($w_{B-A}$)

a, b, c, d, e are equal to \( \frac{1}{2} \) (approach width to nearside of median line)
Each \( \leq 5 \text{ m} \)
a, b, c, d, e are equal to \( \frac{1}{2} \) (approach width to nearside of median line)
Each \( \leq 5 \) m

Lane width measurements for the left-turning minor road stream \( w_{B-C} \)

Figure B1 Measurement of minor road lane widths
Figure B2  Measurement of major road R/T lane width

Lane width measurements for the right-turning major road stream \( w_{C-B} \)

a, b, c, d, e are equal to the lane width where there is explicit provision for left-turners (each \(< 5m\)), and equal 2.2m otherwise.
(a) no bollards

(b) bollards
Figure B3 Components of major road widths
Figure B4 Measurement of visibility to left and right (Vl and Vr)
iii) Visibility distances

a) the minor road stream (VI and Vr) - see Figure B4

The visibility distances for these streams are measured from points 10m back from the give-way line on lines bisecting each lane. Visibility to the left, VI, is measured from the offside lane to a line bisecting the far major road carriageway. Visibility to the right, Vr, is an average of the measurements made from each lane to the line bisecting the near major road carriageway. All measurements are made at a height of 1.05m above the carriageway surface.

The user should note that the Departmental Advice Note for the layout of major/minor priority junctions (TA 20/84) measures visibility from a point 9m back from the give-way line. If this information is available for a junction it may be used instead of the value measured at 10m distance.
For a new junction which is to be constructed to the Department's standard the user may choose to take as input to the program the visibility requirement specified in the standard. In such cases it should be appreciated that the value input will be the minimum visibility at the junction, the actual value possibly being greater. Hence the resulting capacity will equally possibly be a slight under-estimate.

b) the major road -turning stream (VC-B)

This is the distance that can be seen along the major road. One visibility measurement is made, from the mid-point of the -turning lane, or the position assumed by vehicles waiting to turn right, towards the centre line of oncoming major road traffic at a height of 1.05m.

iv) Length of flare

The length of flared section (FLARE) is the maximum number of vehicle lengths back from the give-way line for which vehicles can queue two abreast. A suitable value for average vehicle length is \((5.75 + 6ph)\) metres, where \(ph\) is the proportion of heavy vehicles.
Example

Capacity of priority T-intersection

**Given Data:**

**Geometric data:**

<table>
<thead>
<tr>
<th>Width in m</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$W =$</td>
<td>10.5</td>
</tr>
<tr>
<td>$WCR =$</td>
<td>2.5</td>
</tr>
<tr>
<td>$WB-A =$</td>
<td>3.4</td>
</tr>
<tr>
<td>$WB-C =$</td>
<td>3.4</td>
</tr>
<tr>
<td>$WC-B =$</td>
<td>2.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Visibility in m</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$VI B-A =$</td>
<td>30</td>
</tr>
<tr>
<td>$Vr B-A =$</td>
<td>35</td>
</tr>
<tr>
<td>$VI B-C =$</td>
<td>40</td>
</tr>
<tr>
<td>$VI C-B =$</td>
<td>120</td>
</tr>
</tbody>
</table>

**Traffic Flow Data (pcu/h):**

**Major Road Streams:**

<table>
<thead>
<tr>
<th>$q =$</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$A-C =$</td>
<td>245</td>
</tr>
<tr>
<td>$A-B =$</td>
<td>204</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$q =$</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$306$</td>
<td></td>
</tr>
</tbody>
</table>

**Minor Road Streams:**

<table>
<thead>
<tr>
<th>$q =$</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$B-A =$</td>
<td>224</td>
</tr>
<tr>
<td>$B-C =$</td>
<td>265</td>
</tr>
<tr>
<td>$C-B =$</td>
<td>255</td>
</tr>
</tbody>
</table>
### Calculations

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>( Y = )</td>
<td>0.64</td>
</tr>
<tr>
<td>( D = )</td>
<td>0.84</td>
</tr>
<tr>
<td>( E = )</td>
<td>0.91</td>
</tr>
<tr>
<td>( F = )</td>
<td>0.86</td>
</tr>
</tbody>
</table>

### Capacity of non-priority streams:

<table>
<thead>
<tr>
<th></th>
<th>RFC</th>
<th>Check</th>
</tr>
</thead>
<tbody>
<tr>
<td>( q_{B-A} )</td>
<td>381.93</td>
<td>( 0.59 )</td>
</tr>
<tr>
<td>( q_{B-C} )</td>
<td>606.60</td>
<td>( 0.44 )</td>
</tr>
<tr>
<td>( q_{C-B} )</td>
<td>553.43</td>
<td>( 0.46 )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>( WB-C = )</th>
<th>( WC-B = )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 10 )</td>
<td>( 7 )</td>
<td>( 6 )</td>
</tr>
<tr>
<td>( 5.5 )</td>
<td>( 5.5 )</td>
<td>( 5.5 )</td>
</tr>
</tbody>
</table>

**Max Minor Road Flow in the design year:**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>( q_{B-A} )</td>
<td>325</td>
<td>45%</td>
</tr>
<tr>
<td>( q_{B-C} )</td>
<td>516</td>
<td>95%</td>
</tr>
<tr>
<td>( q_{C-B} )</td>
<td>470</td>
<td>84%</td>
</tr>
</tbody>
</table>

average = 6.8

= 3.4