ESTIMATION OF PERFORMANCE – TWO-WAY STOP-CONTROLLED INTERSECTION

A TWSC intersection is an intersection in which the movements on one street (labeled the minor street) are controlled by stop signs, while the movements on the other street (labeled the major street) are not stop controlled. The planning method for TWSC intersections is based on the operational analysis method described in chapter 19 of the HCM 2010.

The TWSC intersection planning method predicts the capacity and delay for all minor stream movements at a TWSC intersection. The method estimates the capacity of a minor stream movement based on the conflicting flows of higher priority traffic streams, and the critical headway and follow up headway of the minor traffic stream.

Assumptions, Limitations & Data Requirements

The planning method for TWSC intersections has the following limitations:

- There are no pedestrians at the intersection.
- There is no median barrier on the major street, so all gap acceptance processes from the minor street occur in one step.
- The flow on the major street arrives as a random process, with no platooning from any upstream traffic signals.
- An exclusive lane is provided for left-turning traffic on the major street.
- Short right turn lanes are not considered.
- U-turns are not considered.

The TWSC intersection planning method requires four inputs.

- The demand volumes V_i (veh/h) for each movement
- The proportion of heavy vehicles P_{HV} for each movement
- The number of lanes (and the turn designation for each) on each approach, and
- The peak hour factor PHF for the intersection, either supplied by the analyst or assuming a default value of 0.92.

Estimating V/C Ratio – TWSC Intersections

The method includes eight steps, shown in Exhibit J-1 and described below.

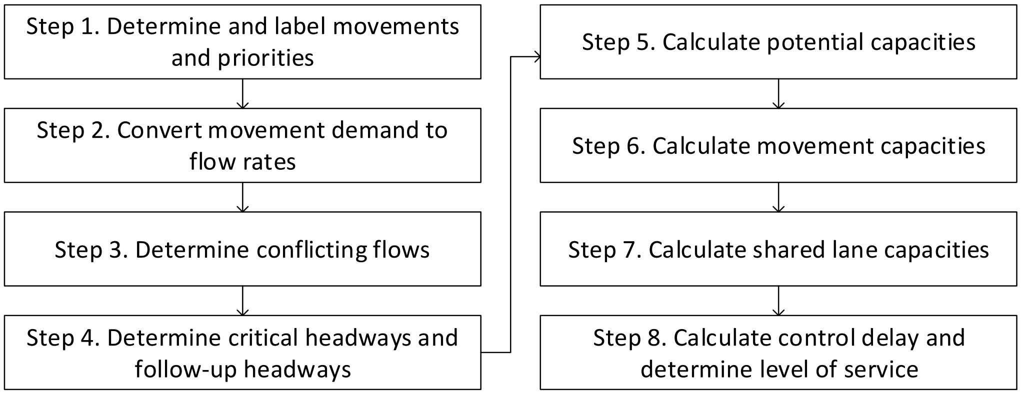

Exhibit J-1: TWSC Intersection Planning Method, Computational Steps

Step 1: Determine Movement Priorities

Determine and label movements and priorities using the numbering scheme from Exhibit J-2. The movements are ranked according to the following priorities.

- Rank 1 includes the through movements on the major street, movements 2 and 5.
- Rank 2 includes the major street left turn movements (1 and 4) and the minor street right turn movements.
- Rank 3 includes the minor street through movements (8 and 11).
- Rank 4 includes the minor street left turn movements (7 and 10).

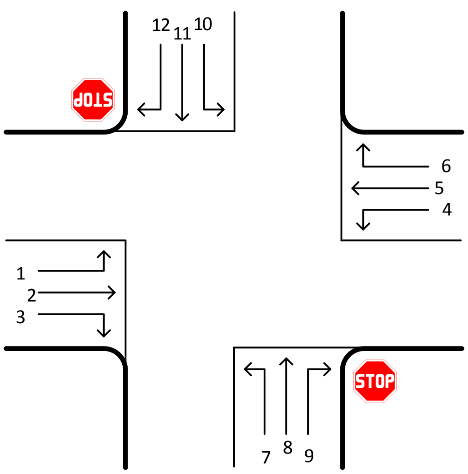

Exhibit J-2: Turning Movement Numbering for TWSC Intersection

Step 2: Compute Flow Rates from Demands

Convert movement demand volumes to flow rates using Equation J-1.

Equation J-1

$$v_i = \frac{V_i}{PHF}$$

where

v_i = demand flow rate for movement i (veh/h)
V_i = demand volume for movement i (veh/h), and
PHF = peak hour factor (default = 0.92)

Step 3: Determine conflicting flow rates.

Each non-rank 1 movement faces a unique set of conflicting flows through which the movement must maneuver. For example, a minor street through movement conflicts with one higher ranked movement (its opposing major street left turn movement) while the minor street left turn movement conflicts with up to three higher ranked movements (the major street left turn movements, the opposing minor street through movement, and the opposing minor street right turn movement). The conflicting flows ($v_{c,x}$) for each movement are calculated using the equations below. The demand flow rates (v_i, where is ranges from 1 to 12 as per Exhibit J-2) are the independent variables in each of these equations.

Conflicting flows for the major street left turning movements (1 and 4) are calculated using Equation J-2 and Equation J-3:

Equation J-2

$$v_{c,1} = v_5 + v_6$$

Equation J-3

$$v_{c,4} = v_2 + v_3$$

Conflicting flows for the minor street right turning movements (9 and 12) are calculated using Equation J-4 through Equation J-7 depending on the number of lanes on the major street:

Two-lane major streets:

Equation J-4

$$v_{c,9} = v_2 + 0.5v_3$$

Equation J-5

$$v_{c,12} = v_5 + 0.5v_6$$

Four and six-lane major streets:

Equation J-6

$$v_{c,9} = 0.5v_2 + 0.5v_3$$

Equation J-7

$$v_{c,12} = 0.5v_5 + 0.5v_6$$

Conflicting flows for the minor street through movements (8 and 11) are calculated using Equation J-7 and Equation J-8:

Equation J-8

$$v_{c,8} = 2v_1 + v_2 + 0.5v_3 + 2v_4 + v_5 + v_6$$

Equation J-9

$$v_{c,11} = 2v_4 + v_5 + 0.5v_6 + 2v_1 + v_2 + v_3$$

Conflicting flows for the minor street left turn movements (7 and 10) are calculated using Equation J-10 through Equation J-15 depending on the number of lanes on the major street:

Two-lane major streets:

Equation J-10

$$v_{c,7} = 2v_1 + v_2 + 0.5v_3 + 2v_4 + v_5 + 0.5v_6 + 0.5v_{12} + 0.5v_{11}$$

Equation J-11

$$v_{c,10} = 2v_4 + v_5 + 0.5v_6 + 2v_1 + v_2 + 0.5v_3 + 0.5v_9 + 0.5v_8$$

Four-lane major streets:

Equation J-12

$$v_{c,7} = 2v_1 + v_2 + 0.5v_3 + 2v_4 + 0.5v_5 + 0.5v_{11}$$

Equation J-13

$$v_{c,10} = 2v_4 + v_5 + 0.5v_6 + 2v_1 + 0.5v_2 + 0.5v_8$$

Six-lane major streets:

Equation J-14

$$v_{c,7} = 2v_1 + v_2 + 0.5v_3 + 2v_4 + 0.4v_5 + 0.5v_{11}$$

Equation J-15

$$v_{c,10} = 2v_4 + v_5 + 0.5v_6 + 2v_1 + 0.4v_2 + 0.5v_8$$

Step 4: Determine critical headways and follow-up headways.

Step 4a: Calculate the critical headway $t_{c,x}$ (s) for each movement x using Equation J-16.

Equation J-16

$$t_{c,x} = t_{c,base} + t_{c,HV} P_{HV}$$

where

$t_{c,base}$ = base critical headways from Exhibit J-2 (s),
$t_{c,HV}$ = adjustment factor for heavy vehicles (1.0 for major streets with one lane in each direction; 2.0 for major streets with two or three lanes in each direction (s),
P_{HV} = proportion of heavy vehicles for movement (expressed as a decimal)

Exhibit J-3: Base Critical Headways

Vehicle movement	Two lanes	Four lanes	Six lanes
Left turn from major street (1,4)	4.1	4.1	5.3
Right turn from minor street (9,12)	6.2	6.9	7.1
Through movement from minor street (8,11)	6.5	6.5	6.5
Left turn from minor street (7,10)	7.1	7.5	6.4

Step 4b: Calculate the follow up time $t_{f,x}$ (s) for each movement x using Equation J-17.

Equation J-17

$$t_{f,x} = t_{f,base} + t_{f,HV} P_{HV}$$

where

$t_{f,base}$ = base follow up headway from Exhibit J-4 (s),
$t_{f,HV}$ = adjustment factor for heavy vehicles (0.9 for major streets with one lane in each direction, 1.0 for major streets with two or three lanes in each direction, and
P_{HV} = proportion of heavy vehicles for movement (expressed as a decimal).

Exhibit J-4: Base Follow Up Headways

Vehicle movement	Two lanes	Four lanes	Six lanes
Left turn from major street (1,4)	2.2	2.2	3.1
Right turn from minor street (9,12)	3.3	3.3	3.9
Through movement from minor street (8,11)	4.0	4.0	4.0
Left turn from minor street (7,10)	3.5	3.5	3.8

Step 5: Calculate potential capacities.

The potential capacity for movement x, $c_{p,x}$, (veh/h) is calculated using Equation J-18.

Equation J-18

$$c_{p,x} = v_{c,x} \frac{e^{-v_{c,x} t_{c,x}/3600}}{1 - e^{-v_{c,x} t_{f,x}/3600}}$$

where

$v_{c,x}$ = conflicting flow rate for movement x (veh/h),
$t_{c,x}$ = critical headway for movement x (s), and
$t_{f,x}$ = follow up headway for movement x (s).

Step 6: Calculate Movement Capacities.

The movement capacity $c_{m,j}$ (veh/h) for the rank 2 movements j (major street left turn movements 1 and 4) and minor street right turn movements 9 and 12) is calculated using Equation J-19.

Equation J-19

$$c_{m,j} = c_{p,j}$$

where

$c_{p,j}$ = potential capacity for rank 2 movement j = 1, 4, 9 or 12.

The movement capacity $c_{m,k}$ (veh/h) for the rank 3 movements k (minor street though movements 8 and 11) is calculated using Equation J-20 and Equation J-21.

Equation J-20

$$c_{m,8} = c_{p,8}\left(1 - \frac{v_1}{c_{m,1}}\right)\left(1 - \frac{v_4}{c_{m,4}}\right)$$

where

$c_{p,8}$ = potential capacity (veh/h) for movement 8,
v_1 = volume for movement 1,
v_4 = volume for movement 4,
$c_{m,1}$ = movement capacity for movement 1, and
$c_{m,4}$ = movement capacity for movement 4.

Equation J-21

$$c_{m,11} = c_{p,11}\left(1 - \frac{v_1}{c_{m,1}}\right)\left(1 - \frac{v_4}{c_{m,4}}\right)$$

where

$c_{p,11}$ = potential capacity (veh/h) for movement 11,
v_1 = volume for movement 1,
v_4 = volume for movement 4,
$c_{m,1}$ = movement capacity for movement 1, and
$c_{m,4}$ = movement capacity for movement 4.

The movement capacity $c_{m,7}$ (veh/h) for the rank 4 movement 7 (minor street left turn movement) is calculated using Equation J-22 and Equation J-23.

Equation J-22

$$c_{m,7} = (c_{p,7})(p')(p_{0,12})$$

where

$c_{p,7}$ (veh/h) = potential capacity for movement 7,
$p_{0,12}$ = probability of queue free state for movement 12, and
p' is given by Equation J-23.

Equation J-23

$$p' = 0.65p'' - \frac{p''}{p'' + 3} + 0.6\sqrt{p''}$$

where

$p'' = p_{0,1}p_{0,4}p_{0,11}$, the probability of queue free states for movements 1, 4, and 11.

The movement capacity $c_{m,10}$ (veh/h) for the rank 4 movement 10 (minor street left turn movement) is calculated using Equation J-24 and Equation J-25.

Equation J-24

$$c_{m,10} = (c_{p,10})(p')(p_{0,9})$$

where

$c_{p,10}$ (veh/h) = potential capacity for movement 10,
$p_{0,9}$ = probability of queue free state for movement 9, and
p' is given by Equation J-23.

Equation J-25

$$p' = 0.65p'' - \frac{p''}{p'' + 3} + 0.6\sqrt{p''}$$

where

p" = $p_{0,1}p_{0,4}p_{0,11}$, the probability of queue free states for movements 1, 4, and 11.

Step 7: Calculate shared lane capacity c_{SH} (veh/h) of the two minor street approaches using Equation J-26.

Equation J-26

$$c_{SH} = \frac{\sum_y v_y}{\sum_y \frac{v_y}{c_{m,y}}}$$

where

v_y = flow rate of movement y in the subject shared lane (veh/h), and
$c_{m,y}$ = movement capacity of movement y in the subject shared lane (veh/h).

Delay – TWSC Intersections

Control delay d (s/veh) is calculated using Equation J-27.

Equation J-27

$$d = \frac{3600}{c_{m,x}} + 900T\left[\frac{v_x}{c_{m,x}} - 1 + \sqrt{\left(\frac{v_x}{c_{m,x}} - 1\right)^2 + \frac{\left(\frac{3600}{c_{m,x}}\right)\left(\frac{v_x}{c_{m,x}}\right)}{450T}}\right] + 5$$

where:

v_x = flow rate for movement x (veh/h),
$c_{m,x}$ = capacity of movement x (veh/h),
T = analysis time period (default = 0.25 h)

The approach control delay for all vehicles on an approach d_A (s) is calculated using Equation J-28.

Equation J-28

$$d_A = \frac{d_r v_r + d_t v_t + d_l v_l}{v_r + v_t + v_l}$$

where

d_r, d_t, d_l = computed control delay for the right-turn, through, and left-turn movements, (s/veh), and
v_r, v_t, v_l = flow rate of right-turn, through, and left-turn traffic on the approach, (veh/h).

The intersection control delay is calculated using Equation J-29.

Equation J-29

$$d_I = \frac{d_{A,1} v_{A,1} + d_{A,2} v_{A,2} + d_{A,3} v_{A,3} + d_{A,4} v_{A,4}}{v_{A,1} + v_{A,2} + v_{A,3} + v_{A,4}}$$

where

$d_{A,x}$ = control delay on approach *x* (s/veh), and
$v_{A,x}$ = flow rate on approach *x* (veh/h).

J6. LEVEL OF SERVICE ANALYSIS

The level of service ranges for stop-controlled intersections are given in Exhibit J-5 based on control delay. Note that if the volume-to-capacity ratio exceeds one, the level of service will be F regardless of the control delay.

Exhibit J-5: Level of Service - Stop Controlled Intersections

Control Delay (s/veh)	X ≤ 1.0	X > 1.0
≤10	A	F
>10–15	B	F
>15–25	C	F
>25–35	D	F
>35–50	E	F
>50	F	F

Adapted from exhibit 20-2, 2010 HCM