

HCM 2010: ROUNDAABOUTS



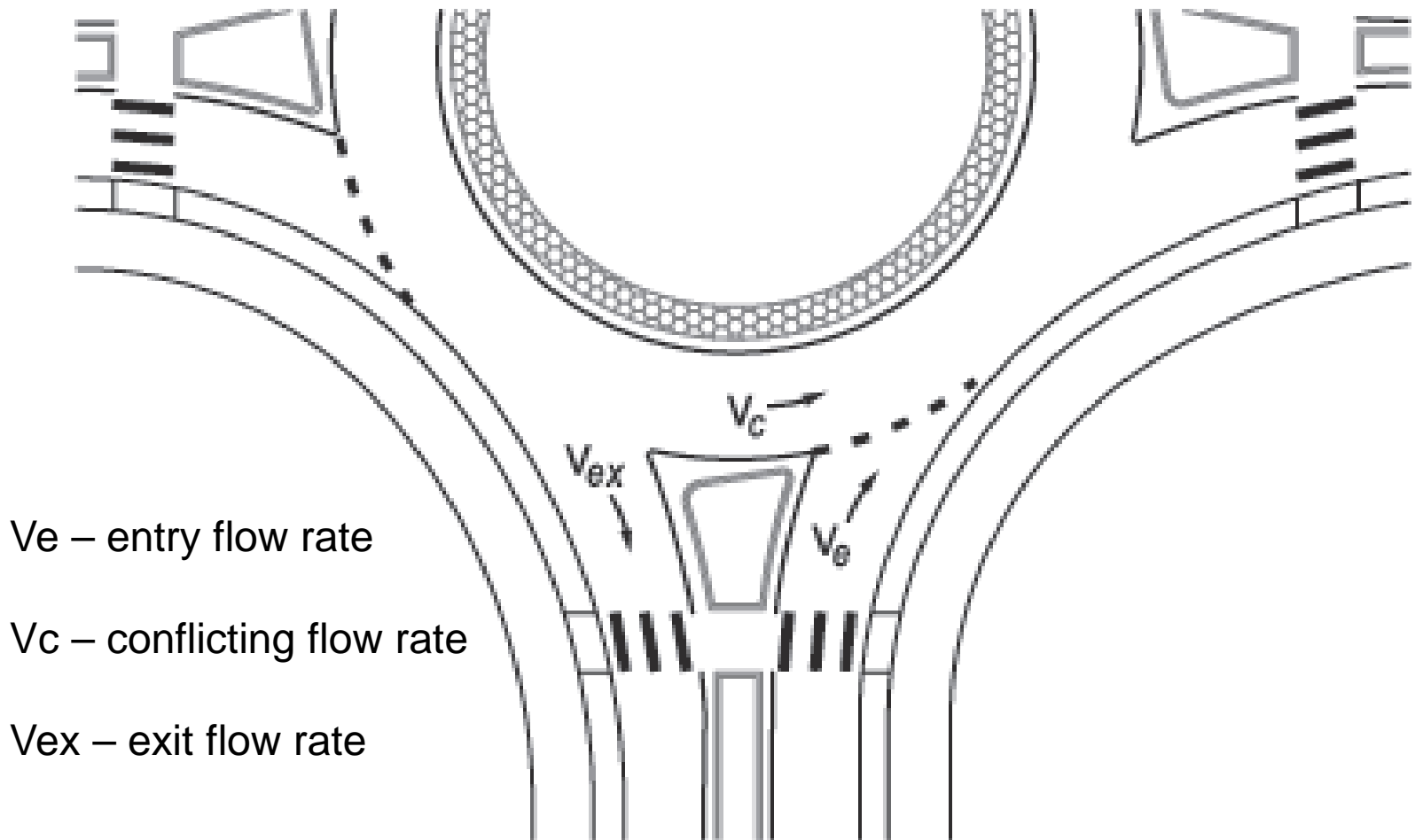
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OUTLINE

- ◆ **Terminology used**
- ◆ **Input data needs**
- ◆ **Capacity of single and multilane roundabouts**
- ◆ **Roundabout analysis methodology**
 - ◆ 12-step procedure
 - ◆ Compute average control delay/LOS for lanes, approaches, and entire roundabout intersection
 - ◆ Compute expected queue length for each approach
- ◆ **Exercise problem – single-lane roundabout**

TERMINOLOGY



INPUT DATA NEEDED

- ◆ Number and configuration of lanes on each approach
- ◆ Either of the following:
 - ◆ Demand volume for each entering vehicle movement and pedestrian crossing movement during the peak 15 min, or
 - ◆ Demand volume for each entering vehicle movement and each pedestrian crossing movement during the peak hour, and a peak hour factor for the hour
- ◆ Percentage of heavy vehicles
- ◆ Volume distribution across lanes for multilane entries
- ◆ Length of analysis period (e.g., peak 15-min period within the peak hour)

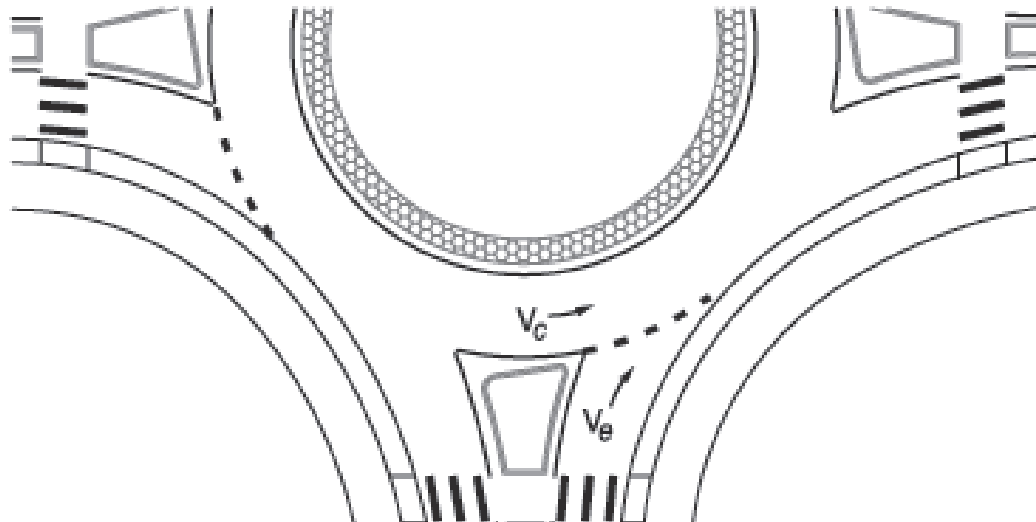
SINGLE LANE ROUNDABOUTS

◆ Capacity of an approach depends on the conflicting flow rate

$$c_{e,pce} = 1,130e^{(-1.0 \times 10^{-3})v_{c,pce}}$$

$c_{e,pce}$ = lane capacity, adjusted for heavy vehicles (pc/h)

$v_{c,pce}$ = conflicting flow rate (pc/h)



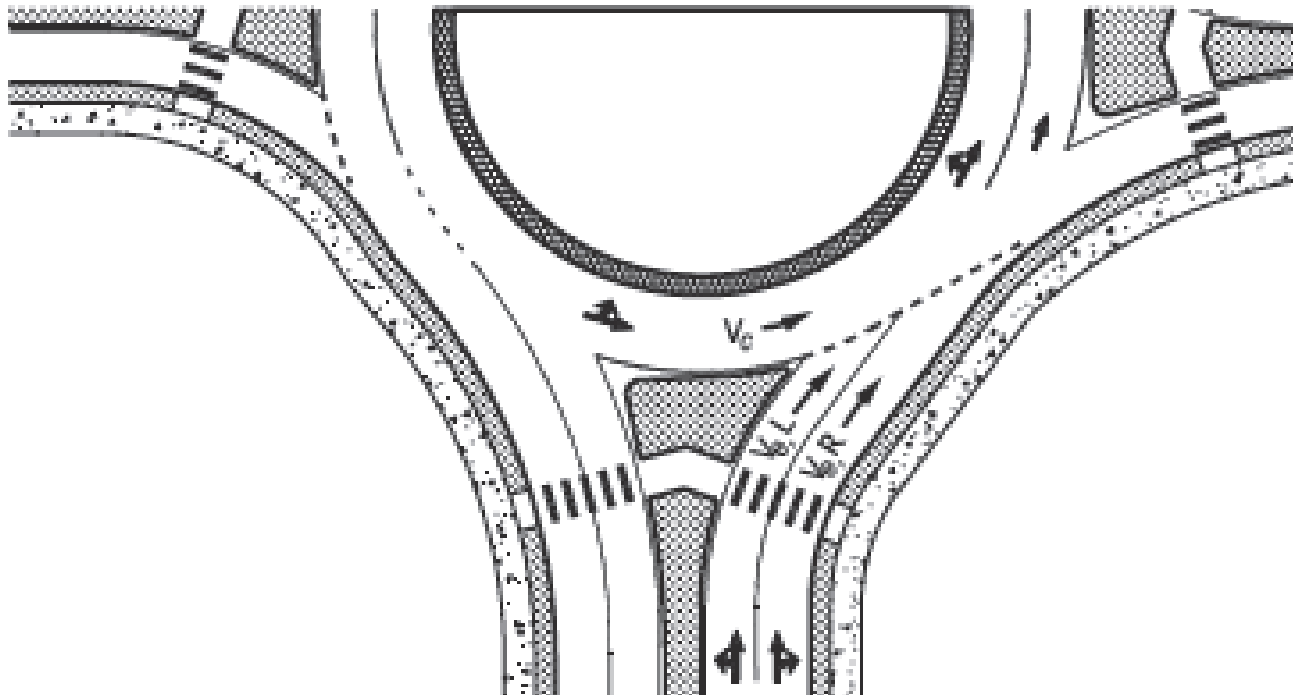
MULTILANE ROUNDABOUTS

- ◆ More than one lane on at least one entry and at least part of the circulatory roadway
- ◆ Number of entry, circulating, and exiting lanes may vary
- ◆ HCM addresses
 - ◆ Up to two circulating lanes
 - ◆ Entries/exits can be either one or two lanes
 - ◆ An additional right-turn bypass lane
- ◆ Capacity calculations depend on the lane configurations

TWO-LANE ENTRY, ONE CIRCULATING LANE

- ◆ Capacity of a two-lane entrance with conflicting flow in only lane

$$c_{e,pce} = 1,130e^{(-1.0 \times 10^{-3})v_{c,pce}}$$

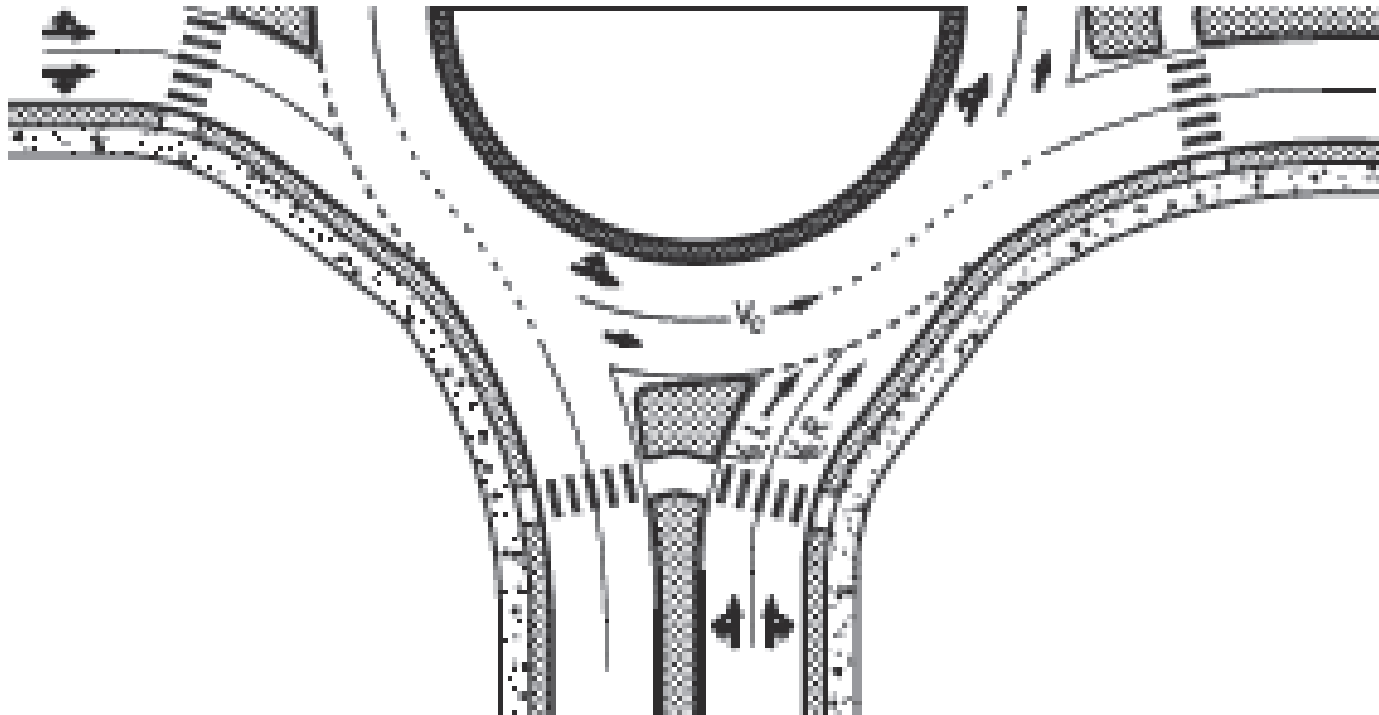


TWO-LANE ENTRY, TWO CIRCULATING LANES

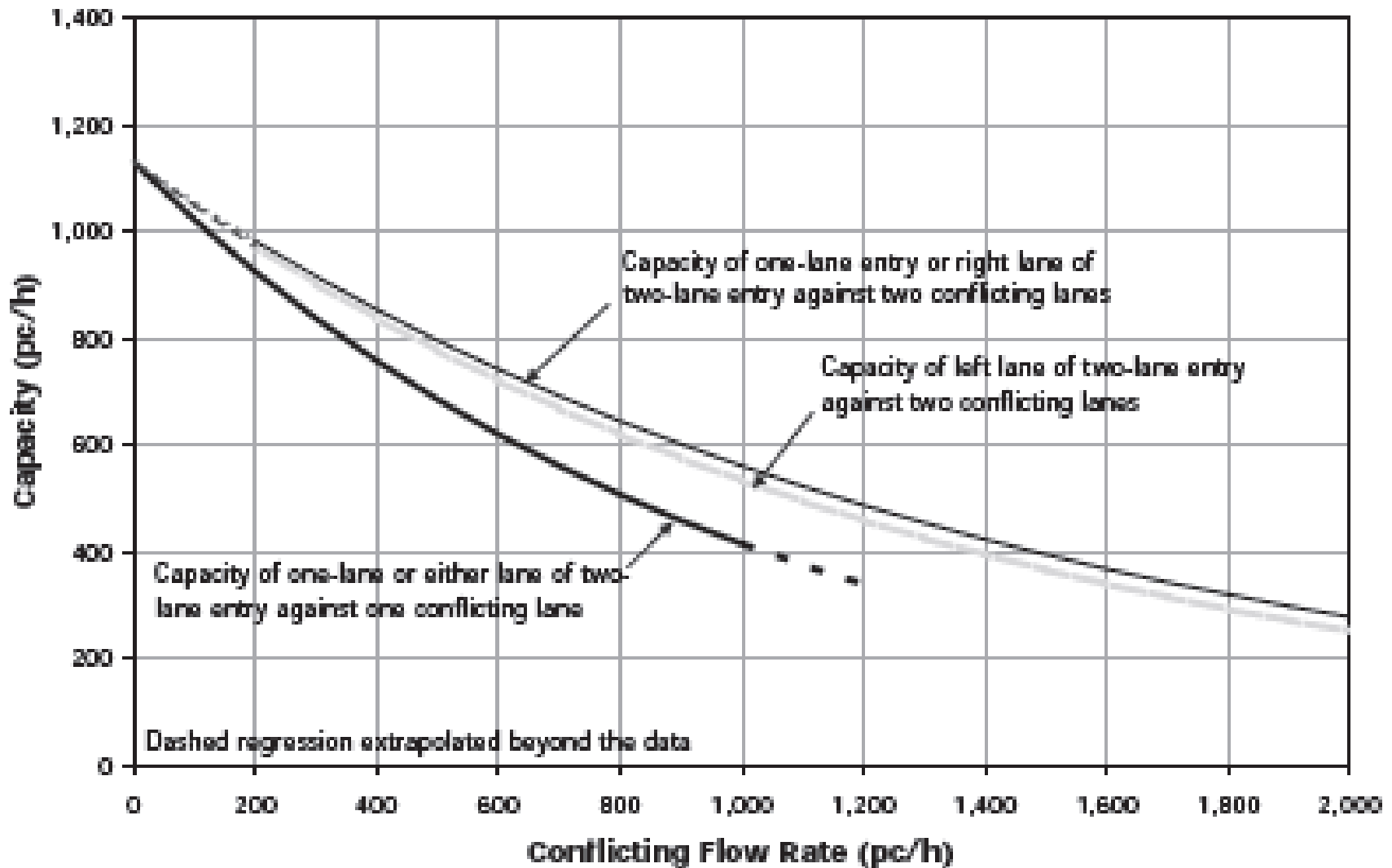
◆ Capacity for right and left lanes

$$C_{e,R,pce} = 1,130e^{(-0.7 \times 10^{-3})v_{c,pce}}$$

$$C_{e,L,pce} = 1,130e^{(-0.75 \times 10^{-3})v_{c,pce}}$$

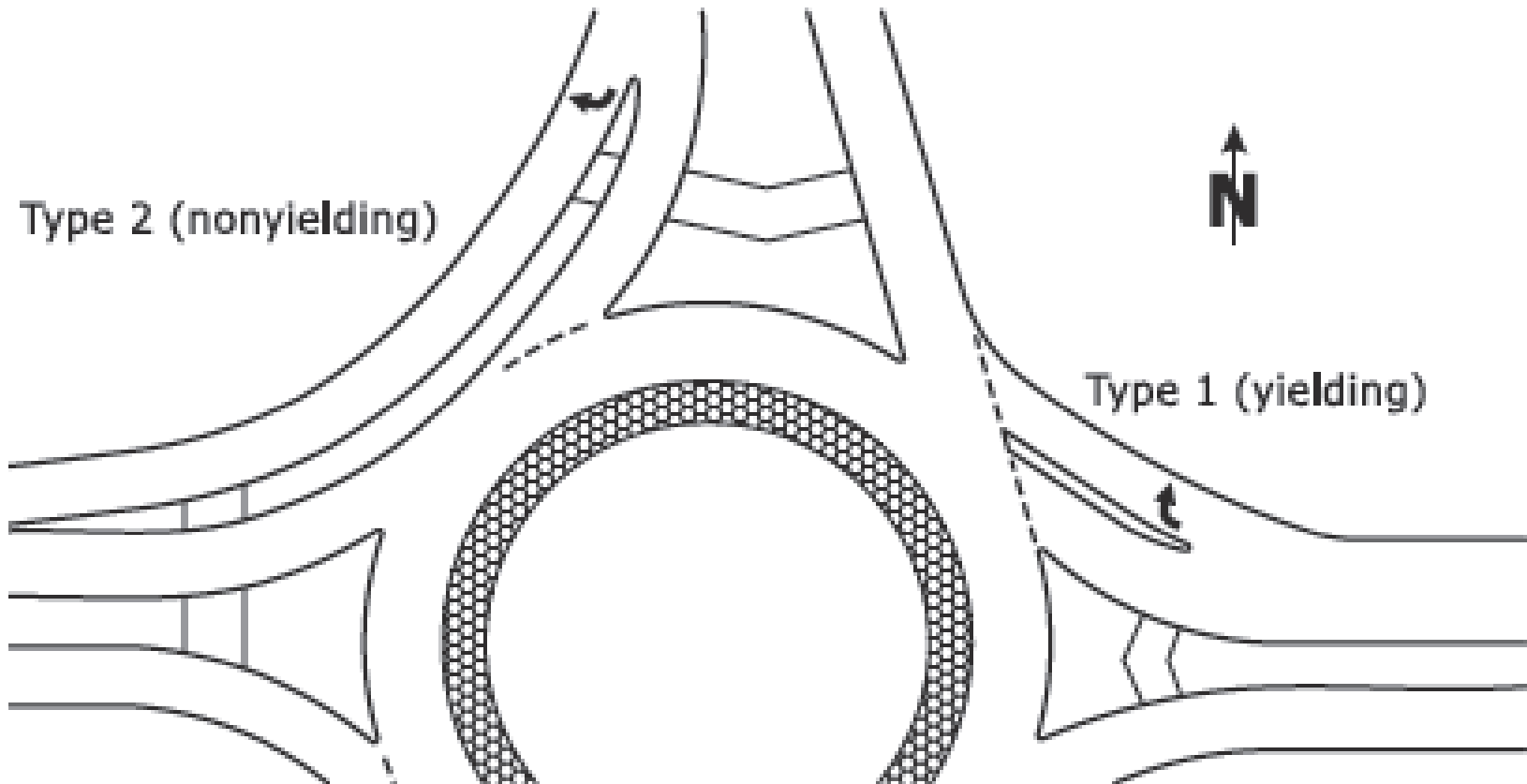


CAPACITY VS CONFLICTING FLOW RATE



RIGHT TURN BYPASS LANES

- ◆ Different formulas for capacity when bypass lanes are present
- ◆ Two types of bypass lanes are included in HCM



ROUNDABOUT ANALYSIS METHODOLOGY

◆ 12 step approach (Steps 1-6)

1. Convert movement demand volumes to flow rates
2. Adjust flow rates for heavy vehicles
3. Determine circulating and exiting flow rates
4. Determine entry flow rates by lane
5. Determine capacity of each entry lane and bypass lane in passenger car equivalents (pce)
6. Determine pedestrian impedance to vehicles

ROUNDABOUT ANALYSIS METHODOLOGY

- ◆ 12 step approach (Steps 7 to 12)
 7. Convert lane flow rates and capacities into vehicles per hour
 8. Compute v/c ratio for each lane
 9. Compute average control delay for each lane
 10. Determine LOS for each lane on each approach
 11. Compute average control delay and LOS for each approach and entire roundabout
 12. Compute 95th percentile queues for each lane



STEP 1 - CONVERT DEMAND VOLUME TO FLOW RATES

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

v_i – demand flow rate for movement i (veh/h)

V_i – demand volume for movement i (veh/h)

PHF – peak hour factor

STEP 2 - ADJUST FLOW RATE FOR HEAVY VEHICLES

$$v_{i,pce} = \frac{v_i}{f_{HV}}$$
$$f_{HV} = \frac{1}{1 + P_T(E_T - 1)}$$

$v_{i,pce}$ – demand flow rate for movement i (pc/h)

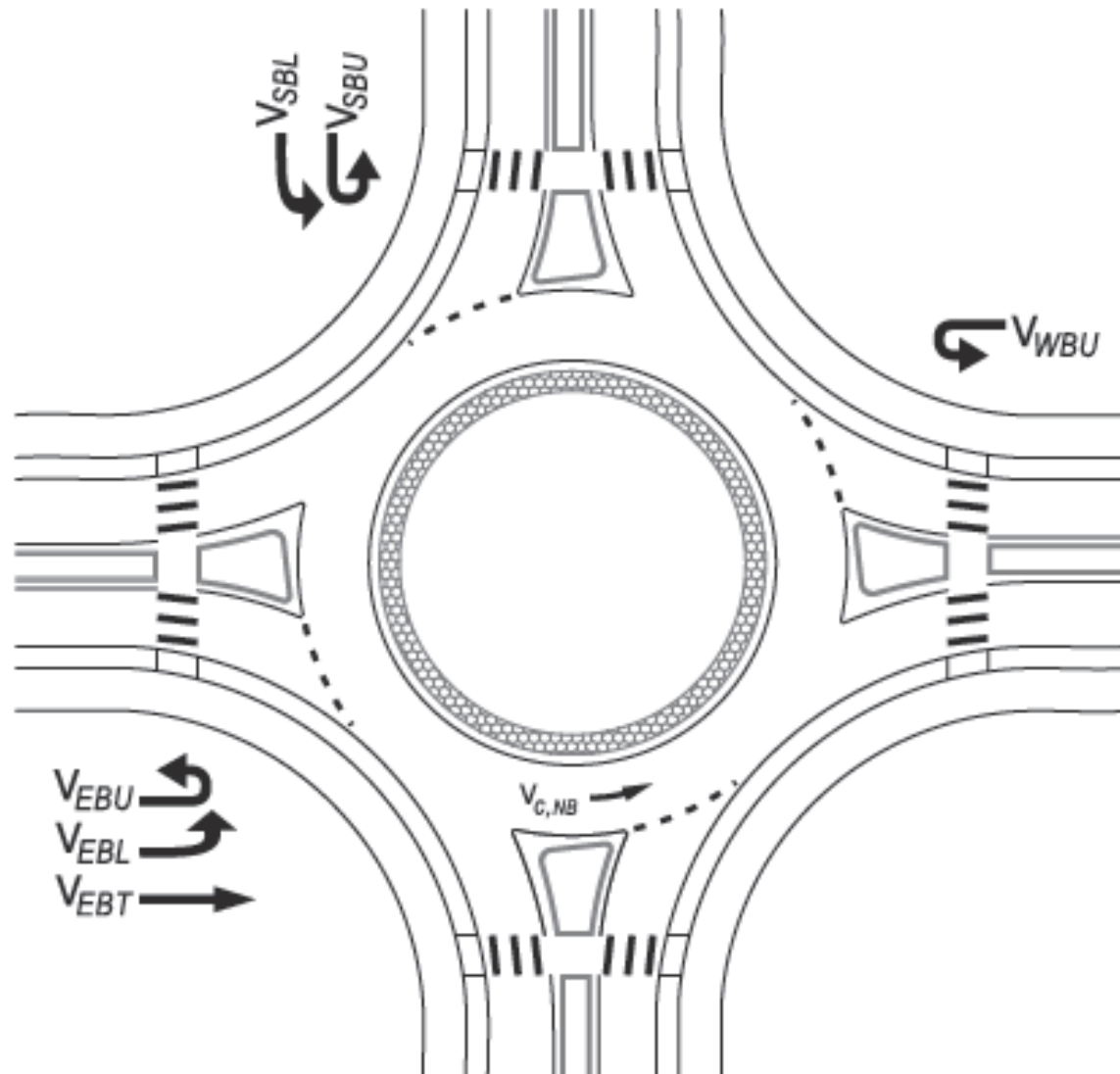
v_i – demand flow rate for movement i (veh/h)

f_{HV} – heavy vehicle adjustment factor

P_T – proportion of demand volume that consists of heavy vehicles

E_T – passenger car equivalent for heavy vehicles

STEP 3 - DETERMINE CIRCULATING FLOW RATE



STEP 4 – ENTRY FLOW RATE BY LANE

- ◆ Determine entry flow rates by lane
 - ◆ Single lane entries –sum of all movement flow rates using that entry
 - ◆ Multilane entries – depends on presence of bypass lanes, lane assignments for different movements
 - ◆ Five lane assignments for two-lane entries
 1. L, TR
 2. LT, R
 3. LT, TR
 4. L, LTR
 5. LTR, R

STEP 5 – ENTRY CAPACITY BY LANE

- ◆ Determine entry lane capacities
 - ◆ Use formulas previously discussed
 - ◆ Capacity depends on number of entry lanes (EL) and conflicting circulating lanes (CL)
 - ◆ Four possible combinations
 1. 1 EL, 1 CL
 2. 2 EL, 1 CL
 3. 1 EL, 2 CL
 4. 2 EL, 2 CL

STEP 6 – DETERMINE PEDESTRIAN IMPEDANCE TO VEHICLES

Case	One-Lane Entry Capacity Adjustment Factor for Pedestrians
If $v_{c,pce} > 881$	$f_{ped} = 1$
Else if $n_{ped} \leq 101$	$f_{ped} = 1 - 0.000137n_{ped}$
Else	$f_{ped} = \frac{1,119.5 - 0.715v_{c,pce} - 0.644n_{ped} + 0.00073v_{c,pce}n_{ped}}{1,068.6 - 0.654v_{c,pce}}$

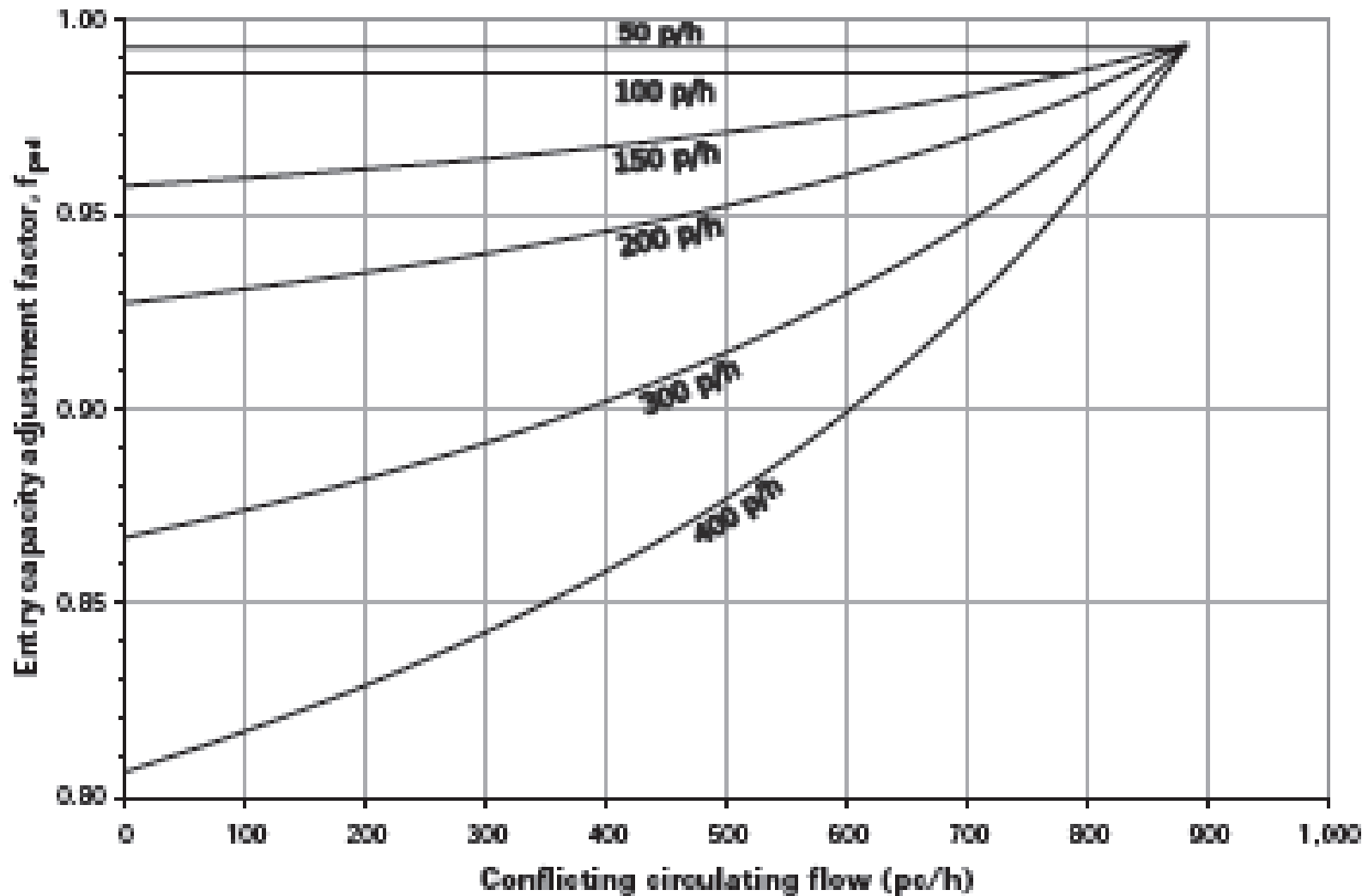
where

f_{ped} = entry capacity adjustment factor for pedestrians,

n_{ped} = number of conflicting pedestrians per hour (p/h), and

$v_{c,pce}$ = conflicting vehicular flow rate in the circulatory roadway, pc/h.

ENTRY CAPACITY ADJUSTMENT FACTOR FOR PEDESTRIANS CROSSING A ONE-LANE ENTRY



STEP 6 – DETERMINE PEDESTRIAN IMPEDANCE TO VEHICLES

Case	Two-Lane Entry Capacity Adjustment Factor for Pedestrians
If $n_{ped} < 100$	$f_{ped} = \min \left[1 - \frac{n_{ped}}{100} \left(1 - \frac{1,260.6 - 0.329v_{c,pc} - 0.381 \times 100}{1,380 - 0.5v_{c,pc}} \right), 1 \right]$
Else	$f_{ped} = \min \left[\frac{1,260.6 - 0.329v_{c,pc} - 0.381n_{ped}}{1,380 - 0.5v_{c,pc}}, 1 \right]$

where

f_{ped} = entry capacity adjustment factor for pedestrians,

n_{ped} = number of conflicting pedestrians (p/h), and

$v_{c,pc}$ = conflicting vehicular flow rate in the circulatory roadway (pc/h).

STEP 7 – CONVERT LANE FLOW RATES AND CAPACITIES INTO VEHICLES PER HOUR

$$v_i = v_{i,PCE} f_{HV,e}$$

$$C_i = C_{i,PCE} f_{HV,e} f_{ped}$$

v_i – demand flow rate for lane i (veh/h)

$v_{i,pce}$ – demand flow rate for lane i (pc/h)

$f_{HV,e}$ – heavy vehicle adjustment factor for the lane (weighted average of adjustment factors for each movement entering roundabout weighted by flow rate)

C_i – capacity for lane i (veh/h)

$C_{i,pce}$ – capacity for lane i (pc/h)

f_{ped} – pedestrian impedance factor

STEP 8 – COMPUTE VOLUME TO CAPACITY RATIO FOR EACH LANE

$$x_i = \frac{v_i}{C_i}$$

v_i – demand flow rate for subject lane i (veh/h)

x_i – volume-to-capacity ratio of the subject lane i

C_i – capacity for the subject lane i (veh/h)

STEP 9 – COMPUTE THE AVERAGE CONTROL DELAY FOR EACH LANE

$$d = \frac{3,600}{c} + 900T \left[x - 1 + \sqrt{(x - 1)^2 + \frac{\left(\frac{3,600}{c}\right)x}{450T}} \right] + 5 \times \min[x, 1]$$

d – average control delay (s/veh)

x – volume-to-capacity ratio of the subject lane

c – capacity for the subject lane (veh/h)

T – time period (h) ($T = 0.25$ h for a 15- min analysis)

STEP 10: LEVEL OF SERVICE

- ◆ Determine LOS for each lane on each approach using below table

Control Delay (s/veh)	LOS by Volume-to-Capacity Ratio	
	$v/c \leq 1.0$	$v/c > 1.0$
0-10	A	F
>10-15	B	F
>15-25	C	F
>25-35	D	F
>35-50	E	F
>50	F	F

STEP 11 – APPROACH AND FACILITY LOS

- ◆ Compute average control delay and determine LOS for each approach and the roundabout as a whole
 - ◆ Approach delay: Weighted average of the delay for each lane on the approach weighted by the volume in each lane

$$d_{\text{approach}} = \frac{d_{LL} v_{LL} + d_{RL} v_{RL} + d_{\text{bypass}} v_{\text{bypass}}}{v_{LL} + v_{RL} + v_{\text{bypass}}}$$

- ◆ Intersection delay: Weighted average of the delay for each approach weighted by the volume on each approach

$$d_{\text{intersection}} = \frac{\sum d_i v_i}{\sum v_i}$$

STEP 12 – COMPUTE 95TH PERCENTILE QUEUES FOR EACH LANE

$$Q_{95} = 900T \left[x - 1 + \sqrt{(1-x)^2 + \frac{\left(\frac{3,600}{c}\right)x}{150T}} \right] \left(\frac{c}{3,600}\right)$$

Q_{95} – 95th percentile queue (veh)

x – volume-to-capacity ratio of the subject lane

c – capacity for the subject lane (veh/h)

T – time period (h) ($T = 1$ for a 1-h analysis)

EXAMPLE PROBLEM

SINGLE-LANE ROUNDABOUT WITH BYPASS LANES