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HIGHWAY CAPACITY MANUAL 2010 UNSIGNALIZED INTERSECTIONS

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Instructor

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Learning Objectives

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Attendee should be able to:

- Describe changes made to the unsignalized methodologies (TWSC, AWSC, and roundabouts).
- Discuss the new roundabout methodologies and applicable applications.

Webinar Objectives

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- Learn about where information on unsignalized intersections can be found in the HCM 2010
- Learn what is new with each of the unsignalized procedures
- Learn background on the development of the new roundabout procedure

Presentation Overview

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- Organization of unsignalized intersection information in HCM 2010
- Two-Way Stop-Controlled (TWSC) Intersections
- All-Way Stop-Controlled (AWSC) Intersections
- Roundabouts

Organization

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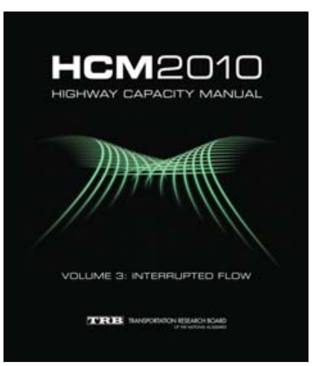
Volume 3: Interrupted Flow



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19. Two-Way STOP-Controlled (TWSC) Intersections
20. All-Way STOP-Controlled (AWSC) Intersections
21. Roundabouts

…

Organization (cont.)

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Volume 4: Applications Guide

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32. Stop-Controlled Intersections: Supplemental
33. Roundabouts: Supplemental

…

Technical Reference Library

- Includes research reports from NCHRP Project 3-46, Report 572, etc.

Presentation Overview

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- Organization of unsignalized intersection information in HCM 2010
- <u>Two-Way Stop-Controlled (TWSC) Intersections</u>
- All-Way Stop-Controlled (AWSC) Intersections
- Roundabouts

TWSC Intersections

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- Core method remains same as HCM 2000
- Basic procedure presented in Chapter 19; more detailed adjustments in Chapter 32
- Chapter reorganized to present material in flow chart form rather than worksheets
- Sample problems provided in both Chapters 19 and 32

Terminology

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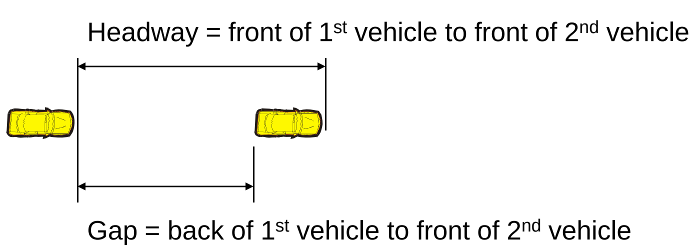
- Term “critical gap” is historic but inaccurate in the HCM procedure
- Replaced with “critical headway”



Parameters for 6-Lane Streets

NEW!

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- Critical headway

Vehicle Movement	Base Critical Headway, $t_{c,base}$ (s) Two Lanes	Four Lanes	Six Lanes
Left turn from major	4.1	4.1	5.3
U-turn from major	N/A	6.4 (wide) 6.9 (narrow)	5.6
Right turn from minor	6.2	6.9	7.1
Through traffic on minor	1-stage: 6.5 2-stage, Stage I: 5.5 2-stage, Stage II: 5.5	1-stage:6.5 2-stage, Stage I: 5.5 2-stage, Stage II: 5.5	1-stage: 6.5* 2-stage, Stage I: 5.5* 2-stage, Stage II: 5.5*
Left turn from minor	1-stage: 7.1 2-stage, Stage I: 6.1 2-stage, Stage II: 6.1	1-stage: 7.5 2-stage, Stage I: 6.5 2-stage, Stage II: 6.5	1-stage: 6.4 2-stage, Stage I: 7.3 2-stage, Stage II: 6.7

* Use caution; values estimated.

- Similar table for follow-up headway

Major-Street U-Turns

NEW!

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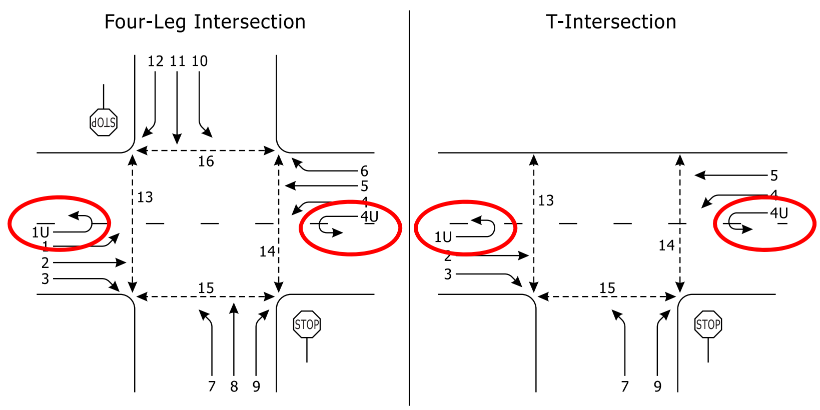
- Method for 4-lane and 6-lane streets



Upstream Signals NEW!

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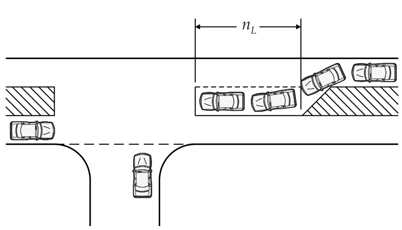
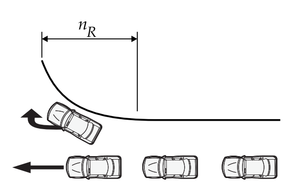
- Method now integrated with urban street segment methodology
- Proportion of time blocked by each direction of major street obtained from Chapter 17 method
  - Explicitly accounts for offsets

Shared and Short Lanes

16

- Models updated





Pedestrian Crossing LOS

NEW!

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- Considers various types of crossing treatments and associated driver yielding behavior

Crossing Treatment	Staged Pedestrians Number of Sites	Staged Pedestrians Mean Yield Rate, %	Unstaged Pedestrians Number of Sites	Unstaged Pedestrians Mean Yield Rate, %
Overhead flashing beacon (push button activation)	3	47	4	49
Overhead flashing beacon (passive activation)	3	31	3	67
Pedestrian crossing flags	6	65	4	74
In-street crossing signs (25–30 mi/h)	3	87	3	90
High-visibility signs and markings (35 mi/h)	2	17	2	20
High-visibility signs and markings (25 mi/h)	1	61	1	91
Rectangular rapid-flash beacon	N/A	N/A	17	81

Source: Fitzpatrick et al. (*11*) and Shurbutt et al. (*12*).

Presentation Overview

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- Organization of unsignalized intersection information in HCM 2010
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- <u>All-Way Stop-Controlled (AWSC) Intersections</u>
- Roundabouts

AWSC Intersections

19

- Core method remains same as HCM 2000
- Restructured to improve user understanding
- Sample problems in both Chapters 20 and 32

Photo: Lee Rodegerdts

Three-Lane Approaches

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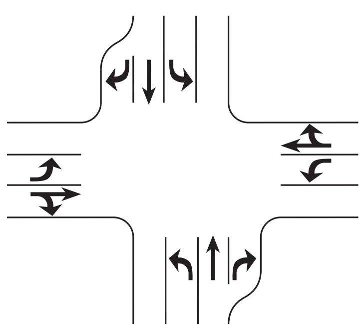
- Chapter 32 provides details to calculate AWSC operation with three-lane approaches



Queuing Model

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- Functionally similar to TWSC queuing model

$$Q_{95} \approx \frac{900T}{h_d}\left[(x-1)+\sqrt{(x-1)^2+\frac{h_d x}{150T}}\right]$$

Presentation Overview

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- Organization of unsignalized intersection information in HCM 2010
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Roundabouts

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- Research background
- Elements of HCM 2010 procedure

Photo: Casey Bergh

NCHRP Report 572

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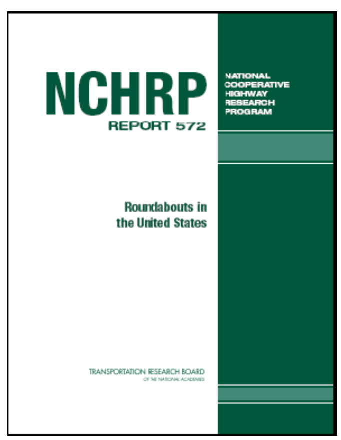
- Most comprehensive study of U.S. roundabout performance to date



NCHRP Report 572 Findings

25

- U.S. capacities lower than observed in other countries
- Capacity clearly sensitive to geometry in the aggregate (number of lanes)
- Secondary effects of geometry on capacity (e.g., lane width, diameter) masked by variations in driver behavior
- Lane-by-lane analysis needed

Why Lower Capacities?

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- Driver unfamiliarity with roundabouts
- Larger vehicles
- Prevalence of stop control
- Lack of use of turn signals on exits

Why Lower Capacities? (cont.)

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- Trends may change over time or by region
  - Calibration exercises in some areas with high roundabout densities show higher capacities
- Suboptimal geometry affects lane use at multilane roundabouts
  - E.g., Poor path alignment can cause drivers to shy away from using left lane to its fullest

Data Supports Simple Models

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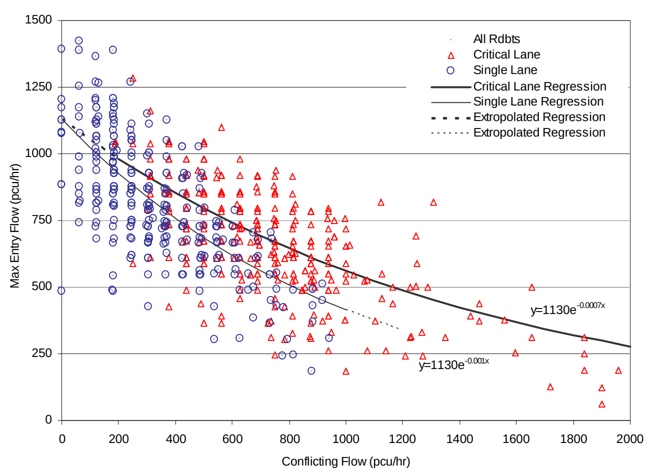

RMSE (root mean square error) of 140-160 vph

Need for Continuing Research

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- More roundabouts in operation today (~2000 in 2010 versus ~300 in 2000)
- More multilane roundabouts today
- Longer adaptation period by drivers
- HCM 2010 procedure has calibration tools to allow procedure to be adapted to empirical, local conditions

Roundabouts

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- Research background
- Elements of HCM 2010 procedure

Photo: Casey Bergh

Flow Rate Calculations

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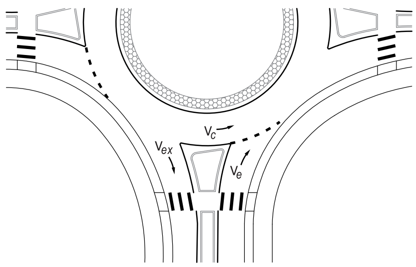

- Calculate flow rates for each entry lane and the conflicting circulatory roadway
- Exit flow rates used for bypass lanes

Flow Rate Adjustments

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- Use of 15-minute flows or Peak Hour Factor (PHF) adjustments
- Passenger Car Equivalent (PCE) adjustment for heavy vehicles (Note: Different from NCHRP Report 572 method)
  - PCE adjustment for circulating flows applied to determine capacity
  - PCE adjustment for entry flows applied to capacity
  - This retains flow rates in vehicles per hour for delay and queuing calculations

Lane Use Assignment

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- Volumes in each entry lane are not assumed to be the same (note: different from NCHRP Report 572 method)
- Influenced by several factors
  - Turning movement patterns
  - Designated lane use
  - Geometry (e.g., lane alignment)
  - Driver behavior
- Default values provided – more research needed in this area

Capacity

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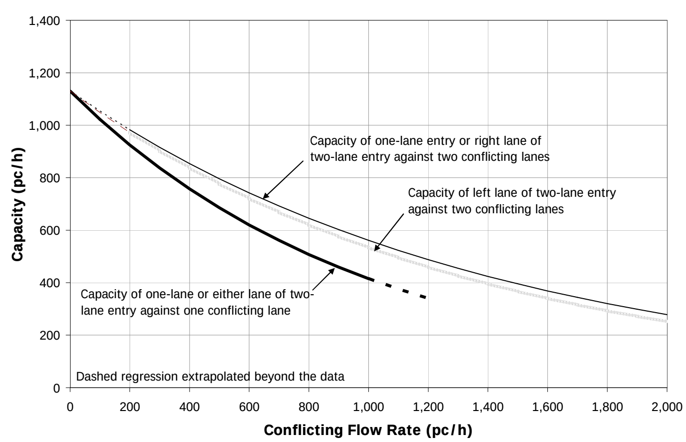

Capacity: 1 lane

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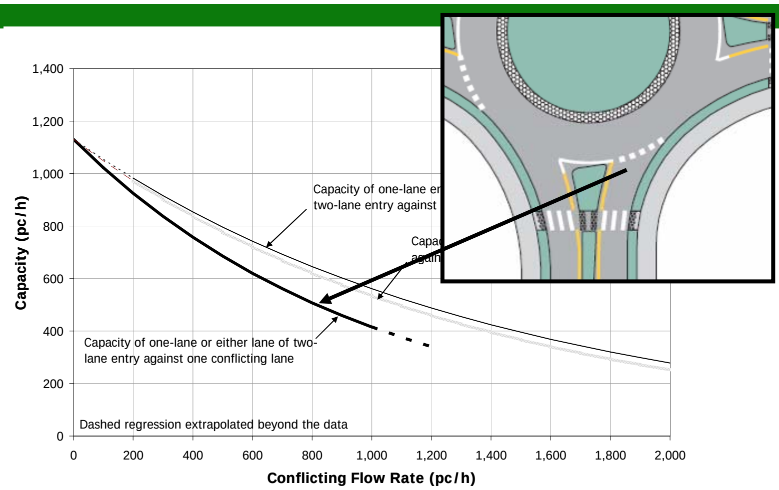
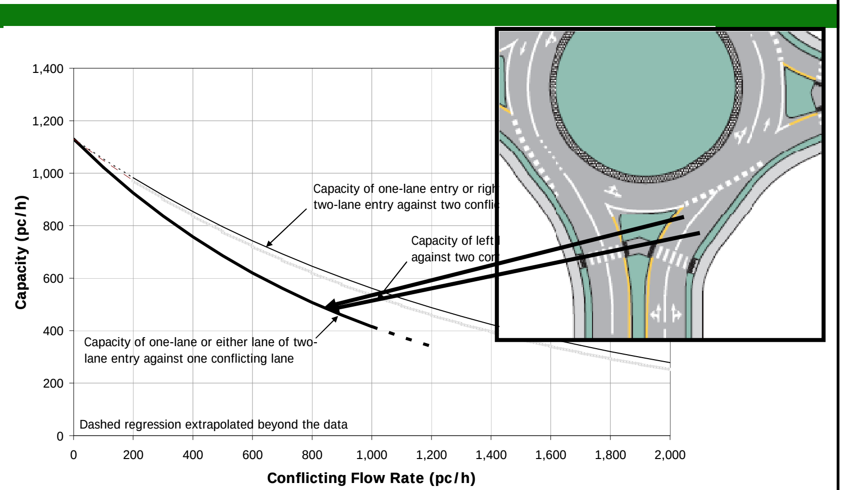


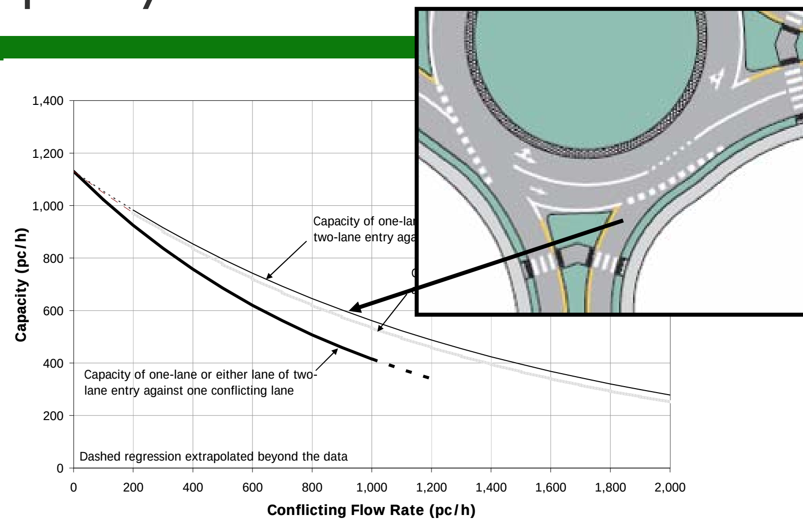
Capacity: 2x1 lane

36



Capacity: 1x2 lane

37



Capacity: 2x2 lane

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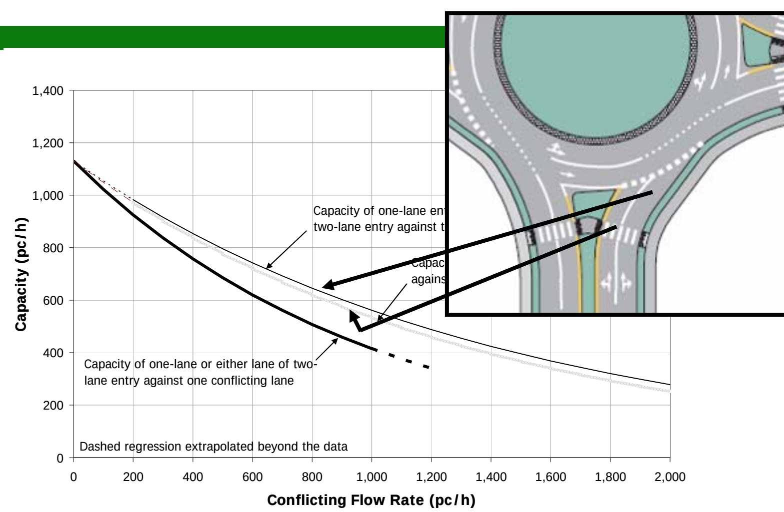

Notes on Capacity Models

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- Entry lanes are analyzed separately
- Model does not distinguish between circulating lanes – models as one flow rate
- Larger data set needed to develop more refined model that explicitly accounts for circulatory lane balance
- Some imbalance in circulatory lane flow rates built in due to empirical study of existing sites

Right-Turn Bypass Lanes

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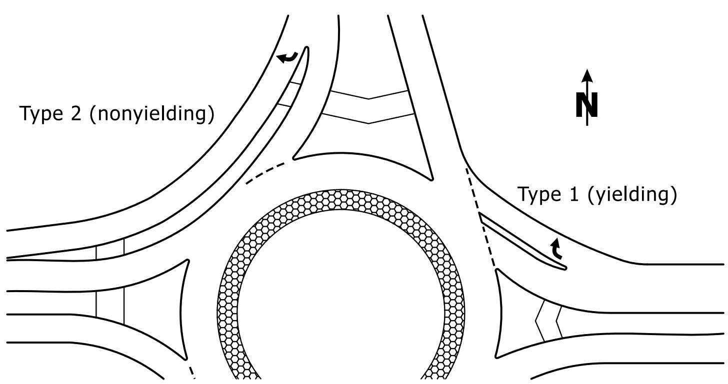
- Two types recognized



Control Delay

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- Same as NCHRP Report 572 recommendation except for modification of last term

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

- Term added to account for likelihood of stopping at high v/c ratios, not stopping at lower v/c ratios

Control Delay (cont.)

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- Approach delay

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

- Intersection delay

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

95th-Percentile Queue

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- Queue equation same as TWSC equation

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

Level of Service

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- Based on control delay
- LOS assigned to each lane, approach, and intersection
- Delay thresholds same as for TWSC and AWSC intersections
  - Similar delay formulation
  - Drivers must select gaps – no guarantee of service

Level of Service (cont.)

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- Considerable discussion on this topic
- Committee recognizes that roundabouts are unique and may ultimately need their own thresholds (as may AWSC)
- Research to affirm existing thresholds or support new thresholds desired

Calibration of Capacity

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- Form of empirical regression model allows for direct calibration to local field conditions

$$c_a = Ae^{(-B\,v_c)} \qquad A = \frac{3600}{t_f} \qquad B = \frac{t_c - (t_f/2)}{3600}$$

- t_c = critical headway
- t_f = follow-up headway

Calibration of Capacity (cont.)

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Single-Lane Roundabouts	NCHRP 572 (2003 data)	California (Tian et al, 2006)	Bend, Oregon (KAI, 2009)
Critical Headway	5.1 s	4.8 s	4.1 s
Follow-up Headway	3.2 s	2.5 s	2.7 s

- Higher single-lane capacity in these examples
  - Drivers more aggressive than national average?
  - Driver history and familiarity?
  - Use of turn signals? (police enforcement/signing)

Alternative Tools

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- HCM 2010 explicitly recognizes that HCM procedures are not the only way to analyze problems
- Applicability to roundabouts
  - Geometric configurations not included in model
  - Oversaturated conditions requiring multiple-period analysis
  - Interaction effects with other intersections

Alternative Tools (cont.)

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- Overview of characteristics of applicable alternative tools for roundabouts
  - Deterministic tools (e.g., ARCADY, RODEL, SIDRA)
  - Simulation (e.g., Paramics, VISSIM)
- Need for calibration to local data (preferred if available) or national averages

Questions?

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- Please send your additional questions & comments to…
  - Lee Rodegerdts (lrodegerdts@kittelson.com)

Thank You

Please provide your feedback. A link to an online evaluation will follow in an e-mail to site registrants. Please distribute this email to participants at your site. The assessment and evaluation will close in one week.

Questions/Comments

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