

# City of Bend Roundabout Analysis and Design Guidelines

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# History of Roundabouts in Bend

- **First roundabout in 1999, developer driven**
- **“Roundabouts First” policy published by City Council in 2001**
- **28 roundabouts constructed (and 15 traffic signals)**



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# Project Objectives and Documents

- **Support City’s “Roundabouts First” policy**
  - *Intersection Form Evaluation Framework*
- **Promote consistency in design**
  - *Roundabout Design Consistency Guidelines*
- **Ensure consistent and locally calibrated analysis**
  - *Roundabout Operational Analysis Guidelines*



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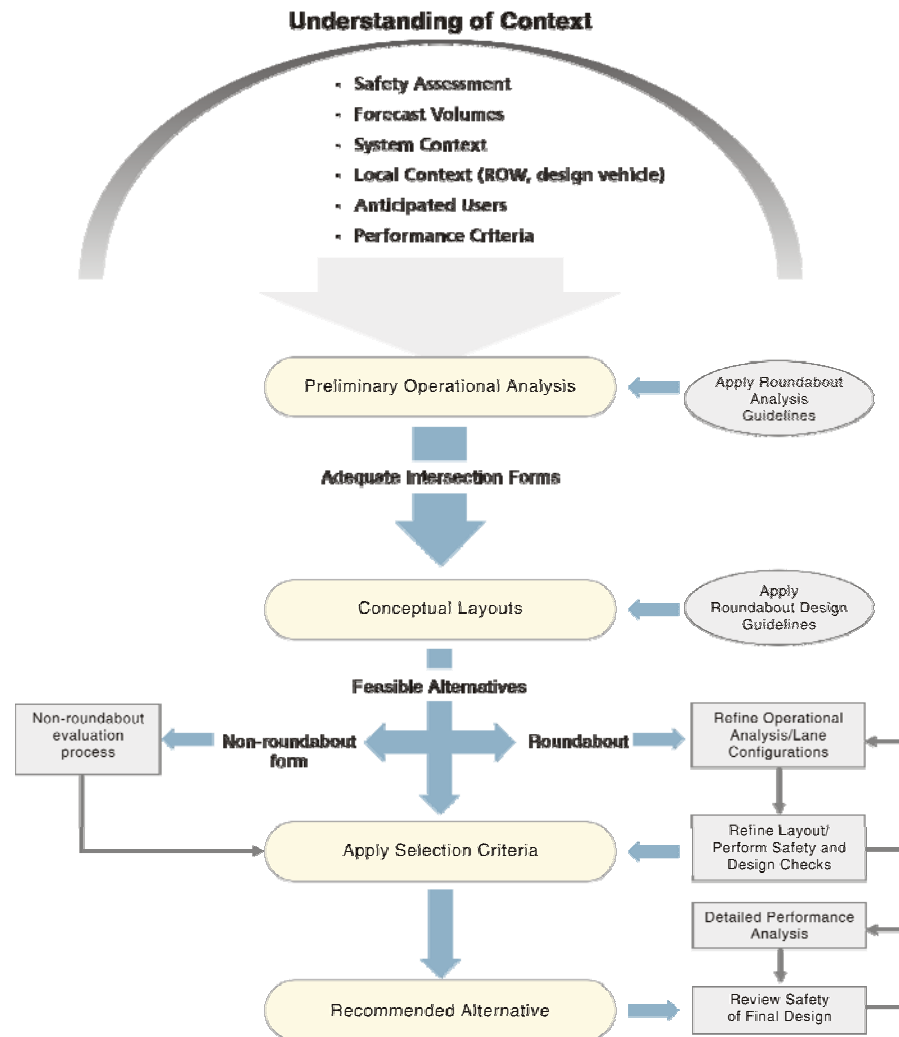
# Intersection Form Evaluation Framework

- **Objective: Promote consistency in evaluation of various intersection forms**
  - “Roundabouts First” policy
  - However, recognize need for flexibility
- **Quantitative and qualitative evaluation criteria**
  - Safety
  - Traffic operations
  - Anticipated users
  - System context
  - Context at intersection
  - Benefit/cost ratios



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# Intersection Form Evaluation Framework



# Intersection Form Evaluation Framework

- Tier 1 Criteria**

Category	Criteria	
<b>Safety</b>		
<b>Motor Vehicle Safety</b>	Conflict points (exposure)	Severity (speed)
<b>Non-Motorized Vehicle Safety</b>	Conflict points (exposure)	Severity (speed)
<b>Traffic Operations</b>		
<b>Peak-Hour Traffic Operations</b>	Volume-to-capacity ratio LOS	Average delay Queue lengths
<b>Anticipated Users</b>		
<b>Design Vehicle</b>	Appropriate heavy vehicle Emergency vehicles	Buses
<b>Special User Needs</b>	School children Visually impaired	Elderly ADA compliance
<b>System Context</b>		
<b>System Effects</b>	Adjacent traffic control Railroad crossing	
<b>Environmental Impact</b>	Land use context	
<b>Emergency Response</b>	Response time/control delay	
<b>Context at Intersection</b>		
<b>Intersection Footprint</b>	Intersection proper (physical & operational influence area) Roadway approach geometry	
<b>Intersection Influence Area</b>	Driveway closures or impacts	



# Intersection Form Evaluation Framework

- Tier 2 Criteria**

Category	Criteria
<b>Safety</b>	
<b>Motor Vehicle Safety</b>	Crash Prediction
<b>Traffic Operations</b>	
<b>Peak Hour Traffic Operations</b>	Sensitivity to changes in volumes/ travel patterns
<b>24-Hour Traffic Operations</b>	Average Delay
<b>Anticipated Users</b>	
<b>Pedestrians</b>	Crossing distances
<b>Bicyclists</b>	Adjacent bike facilities      Intersection specific considerations
<b>System Context</b>	
<b>Environmental Impact</b>	Estimated emissions output
<b>Access Management</b>	Facilitates access management      Median and U-turn opportunities Driveway connections
<b>Emergency Response</b>	Evaluating likely emergency response routes
<b>Context at Intersection</b>	
<b>Environmental Impact</b>	Impervious surface area      Aesthetics
<b>Intersection Influence Area</b>	Approach and segment cross-section
<b>Benefit/Cost Ratio</b>	
<b>Benefits</b>	Crash reduction      Reduced fuel consumption Reduced delay (15-min delay, 24-hour delay)
<b>Costs</b>	Design/Engineering Costs Construction costs including ROW acquisition Operations/maintenance costs (includes energy costs for signals)



# Roundabout Design Consistency Guidelines

- **Objective: Ensure consistent analysis and conclusions**
  - Reinforce design guidelines in FHWA Guide
  - Supplement as needed according to City-specific criteria
- **Design review**
  - Generally a positive evolution in design practice
  - Early designs generally “compact urban”
  - Inconsistencies in speed and design vehicle checks
  - Varying truck apron, entry/exit, and channelization treatments



Photo: Lee Rodegerdts



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# Roundabout Design Consistency Guidelines

- **Design vehicle**
  - Base condition is a WB-50
  - Truck apron
    - Type B curb for outer edge
    - High-strength concrete and reinforcing
  
- **Approach width**
  - Concerns from Fire Department
  - 20' curb to curb
  
- **Promote proper path alignment for multilane entries and exits**



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# Roundabout Design Consistency Guidelines

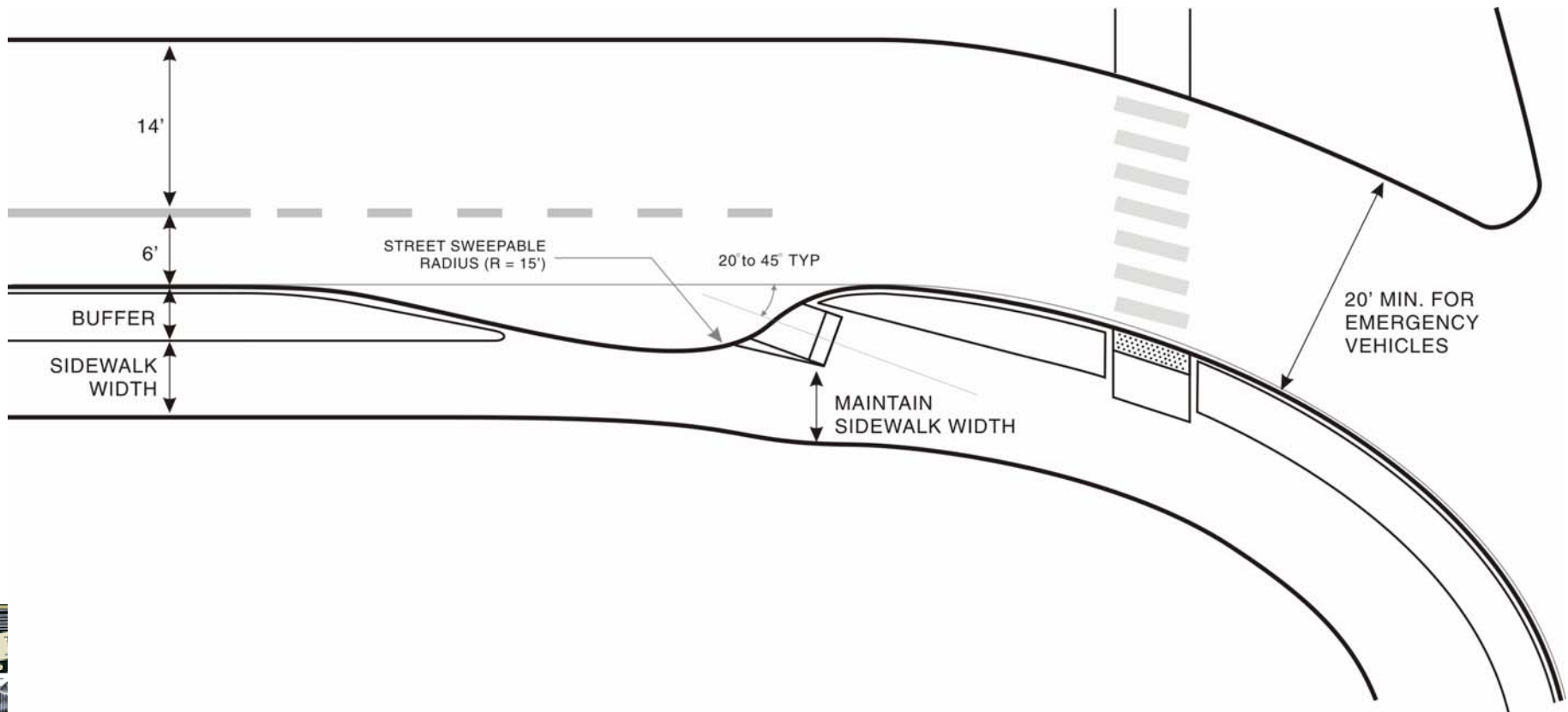
- **Pedestrian treatments**
  - Preferred width for pedestrian refuge area = 8-9'
  - Shared use path = 8' min, 10' preferred
  - Crossings perpendicular to center line
- **Pedestrian signals**
  - Include conduit in all multilane designs



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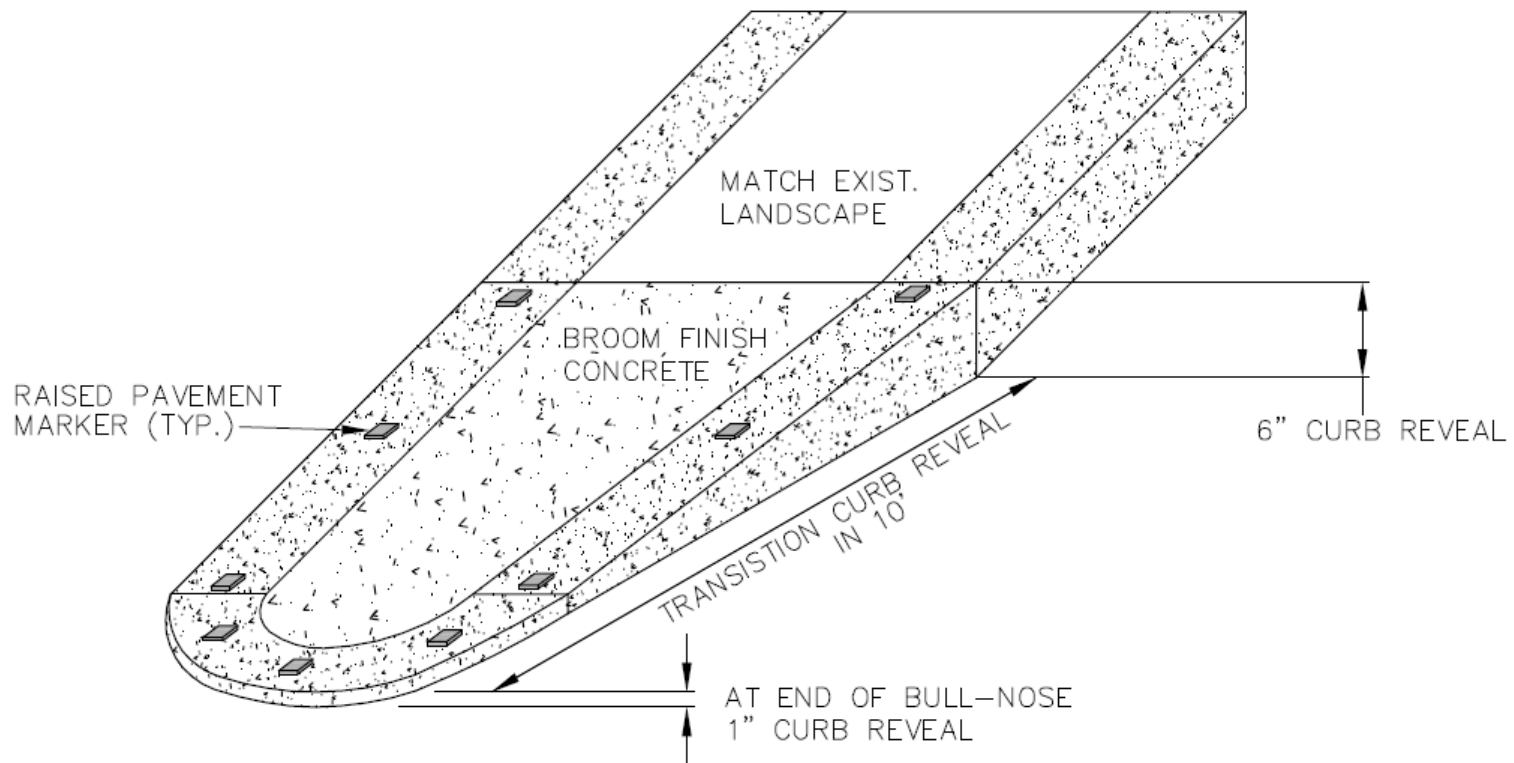
# Roundabout Design Consistency Guidelines

- **Bicycle treatments**



# Roundabout Design Consistency Guidelines

- **Splitter island end treatments**



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# Roundabout Design Consistency Guidelines

- **Illumination**

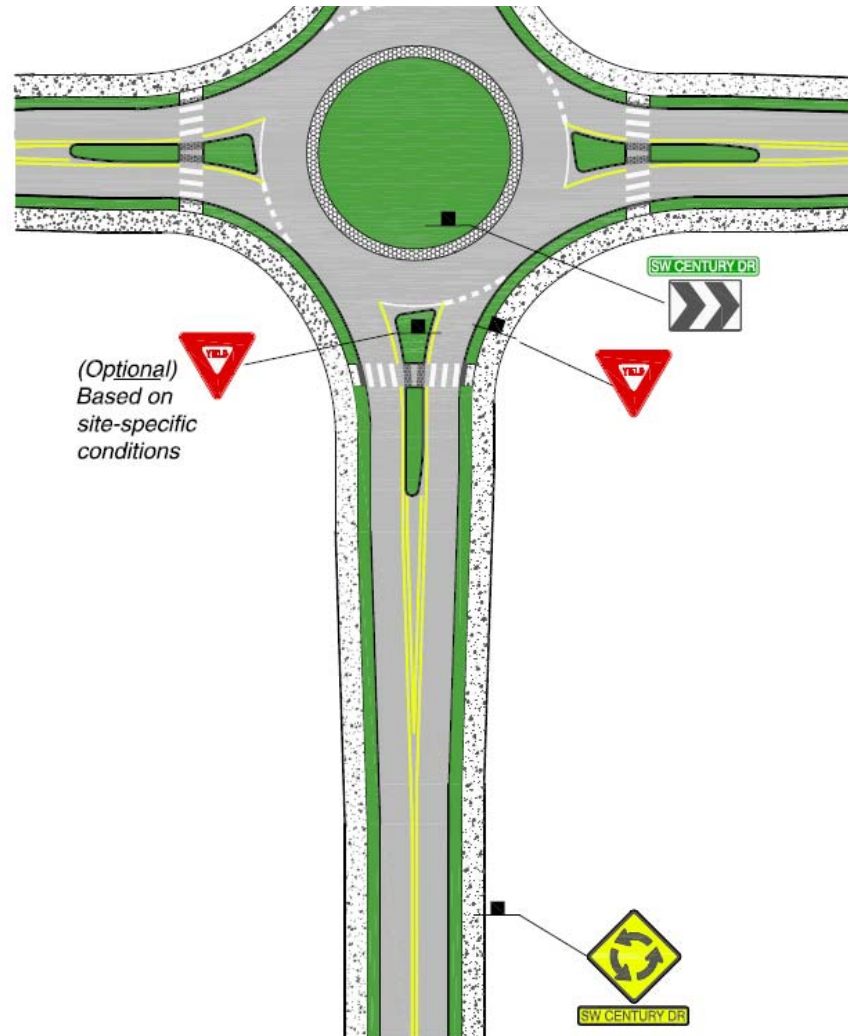
- Concern with over illumination of roundabouts
- Guidelines based on guidance from Illuminating Engineering Society
  - **Illumination at ped crossings placed in advance of crossing**
- Horizontal and vertical illumination
  - **Minimum illuminance of 1.0 foot-candles**
  - **Uniformity of 3:1 or better**



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# Roundabout Design Consistency Guidelines

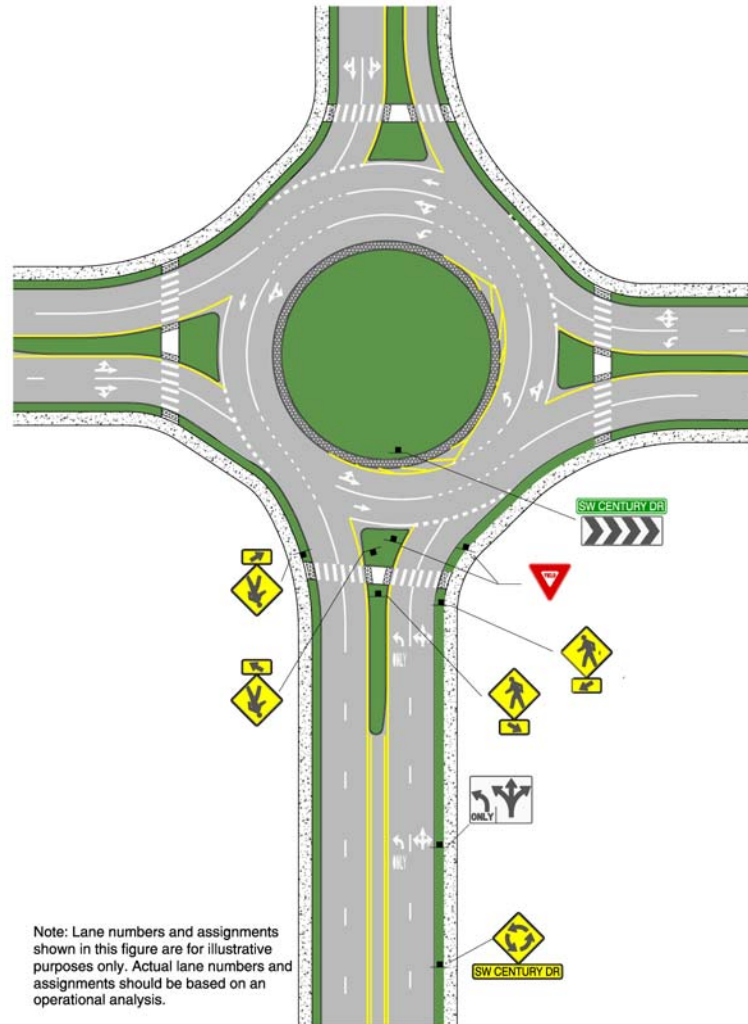
- **Single-lane signing and striping**



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# Roundabout Design Consistency Guidelines

- **Multilane signing and striping**



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# Roundabout Operational Analysis Guidelines

- **Objective: Ensure consistent analysis and conclusions**
  - Development applications
  - Capital improvement projects
  
- **Current (past) practice**
  - City standard:  $v/c \leq 1.0$
  - Variety of analysis methodologies
    - SIDRA
    - RODEL
    - FHWA
  - Range of inputs and assumptions



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# Roundabout Operational Analysis Guidelines

- **Based on NCHRP Report 572 and Draft 2010 HCM**
  - Analysis by approach (single-lane) or critical lane (multilane)
  - Capacity model based on gap acceptance
- **Performance measures**
  - V/C ratio
  - Queuing
  - Delay/LOS



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# Roundabout Operational Analysis Guidelines

- **Local calibration of capacity model**
  - Local driver experience
  - Ensure appropriate buildout of City's infrastructure
  
- **Data collection**
  - Queued conditions
  - Ten single-lane approaches
  - Multiple time periods
  - Varying geometry
  
- **Data collected**
  - Critical gap (rejected and accepted gaps)
  - Follow-up headway



# Roundabout Operational Analysis Guidelines

Measure	Bend	NCHRP 572
Critical Gap	4.1 s	5.1 s
Follow-up Headway	2.7 s	3.2 s

- **Higher single-lane capacity**
  - Driver history and familiarity?
  - Use of turn signals? (police enforcement/signing)
- **Single-lane capacity model**

$$c = 1333 \cdot \exp(-0.0008 \cdot v_c)$$

where,

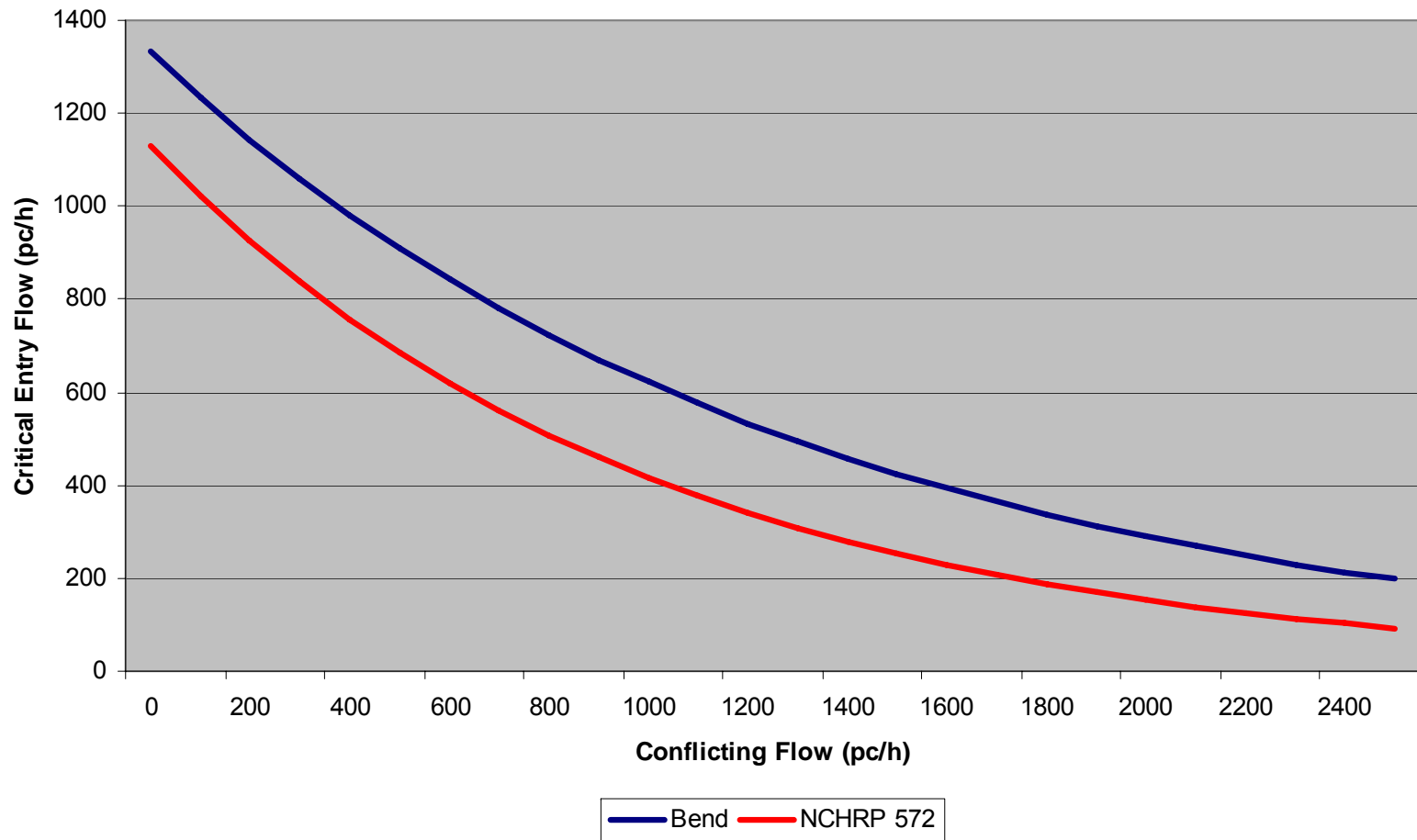
$c$  = entry capacity (pc/hr)

$v_c$  = conflicting circulating volume (pc/hr)



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# Roundabout Operational Analysis Guidelines



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# Roundabout Operational Analysis Guidelines

- **Multilane capacity models**
  - Multilane entry conflicted by one circulating lane
    - Apply single-lane capacity model to critical approach lane
  - Multilane entry conflicted by two circulating lanes
    - Apply NCHRP 572 multilane capacity model to critical approach lane



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# Roundabout Operational Analysis Guidelines

- **Delay and queuing models based on HCM unsignalized models**
- **LOS thresholds based on HCM unsignalized LOS**
- **Option for weighted average of delay for intersection**
- **Alternative analysis tools**



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Photo: Casey Bergh



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