DESIGN CONSIDERATIONS OF MODERN ROUNDABOUTS

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Introduction

Modern Roundabouts have become Popular Worldwide due to their Geometric Design, which, Compared to Other At-grade Intersection Types, Provide:

- speed control (lower vehicular speeds)
- safety performance regarding all users (conflict points reduced, crossing conflicts eliminated)
- efficient traffic control and lower delays (given that their capacity is not exceeded)
- more attractive aesthetics and eco-friendly implementation

Objectives

- Provide a Framework of the Most Critical Geometric Features of Modern Roundabout Design
- Outline a Correlation regarding Design Considerations of Current International Practice and Guidelines between UK, US and Germany
- Investigate whether Innovative Roundabout Layouts Outmatch their more Traditional “Rivals”
  - turbo roundabouts vs 2-lane roundabouts

Basic Roundabout Types (1/3)

- **Mini-Roundabouts**
  - urban use
  - fully traversable central island

Basic Roundabout Types (2/3)

- **Single-Lane Roundabouts**
  - urban and rural use
  - non- traversable central island
  - with or without truck apron

Basic Roundabout Types (3/3)

- **Two-Lane Roundabouts**
  - urban and rural use
  - non- traversable central island
  - with or without truck apron

In Germany, Circulatory Roadway without Lane Markings and Strictly Single-lane Exits (Compact 2-lane Roundabouts)

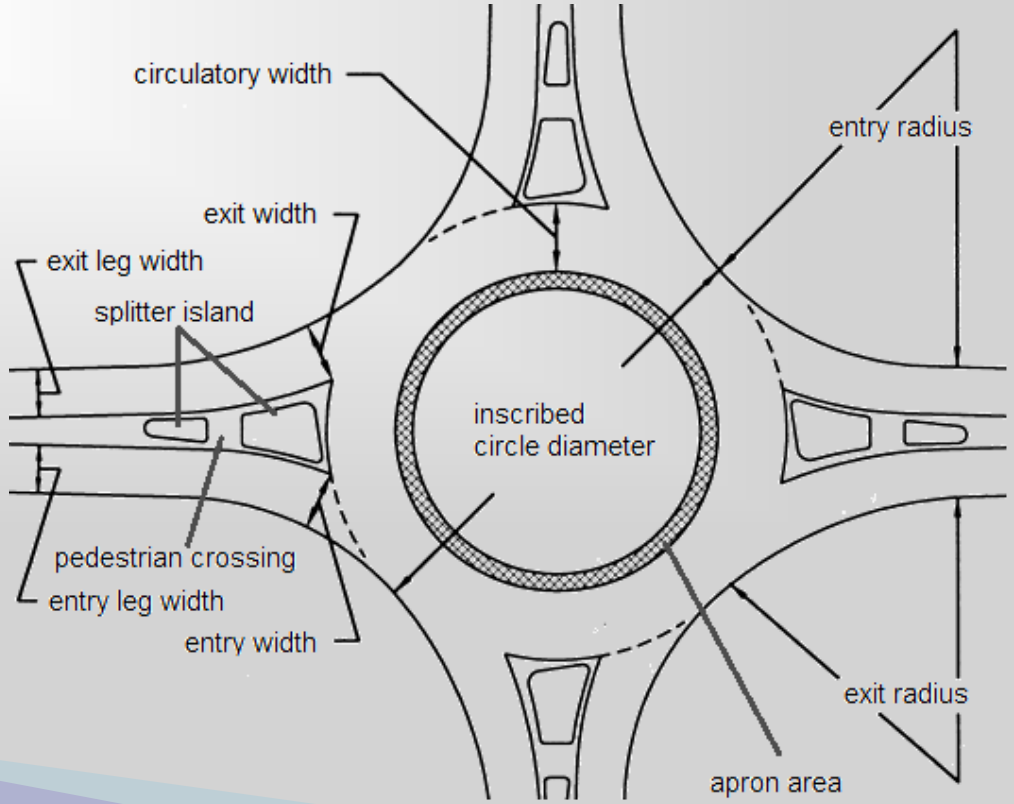
Critical Design Parameters

General

- Roundabout Design Guidelines Reflect a Country's Considerations
  - cultural
  - behavioral
  - environmental
- Control Values for each Geometric Design Element Vary
- Generally UK and US Guidelines Converge Significantly in Most Cases

Critical Design Parameters

Basic Geometric Elements



Critical Design Parameters

Mini Roundabout Guidelines			
Design Element	**UK**	**US**	**German**
Average operating speed (km/h)	—	< 50	< 50
Central island treatment		fully traversable	
Typical inscribed circle diameter (m)	≤ 28	13 - 27	13 - 24
Circulatory roadway width (m)	4.5 – 5.5	4.2 – 5.5	4.5 – 6.0
Typical daily service volumes (veh/day)	not specified	≤ 15,000	≤ 20,000
Entry Lanes	1	1	1
Exit Lanes	1	1	1
Urban - Rural		urban	

Critical Design Parameters

Single-Lane Roundabout Guidelines			
Design Element	**UK**	**US**	**German**
Average operating speed (km/h)	—	< 50	< 50
Central island treatment	raised		
Apron utilization if required	traversable	traversable	traversable (urban)
Typical inscribed circle diameter (m)	28 - 36	27 - 55	26 - 50
Circulatory roadway width (m)	≤ 5.5	≤ 6.5	6.0 – 8.0
Typical daily service volumes (veh/day)	not specified	≤ 25,000	≤ 25,000
Entry Lanes	1	1	1
Exit Lanes	1	1	1
Urban - Rural	urban - rural		

Critical Design Parameters

Multilane Roundabout Guidelines			
Design Element	**UK**	**US**	**German**
Average operating speed (km/h)	—	< 50	< 50
Central island treatment		raised	
Apron utilization if required	traversable	traversable	traversable (urban)
Typical inscribed circle diameter (m)	not specified (even > 100)	46 - 90	40 - 60
Circulatory roadway width (m)	≤ 12.5	8.5 - 9.8 (2 lane) 12.8 - 14.6 (3 lane)	8.0 – 10.0
Typical daily service volumes (veh/day)	not specified	≤ 45,000	≤ 32,000
Entry Lanes		2+	1 or 2
Exit Lanes		2+	1
Urban - Rural	urban - rural	urban - rural	rural (mainly)

Critical Design Parameters

Speed Impact

- Roundabout's Operating Speed Mostly Critical in Terms of Evaluating Safety Performance
- Frequency of Crashes Directly Related to Volume, Severity of Crashes Directly Associated to Speed
- Attention to the Speed of a Roundabout is Fundamental in Order to Attain Good Safety Performance
  - design successive reserve curves of reducing radii values in advance of the roundabout
  - at entry area, between conflicting traffic streams, consistency in the relative speed values is critical
    - ✓ minimize the crash rate
    - ✓ force vehicles to negotiate the roundabout along a curved path

Critical Design Parameters

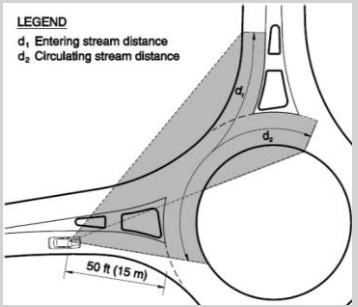
Design Vehicle

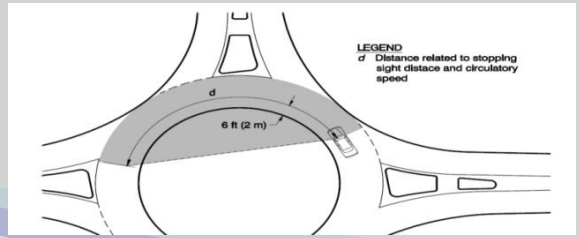
- Accommodation and Maneuvering Requirements (Swept Path) determines in Great Extent the Roundabout's Final Layout (Entry & Exit Radii)
- Simulation of Vehicle's Swept Path is Encouraged via Computer Simulation in all Approaches

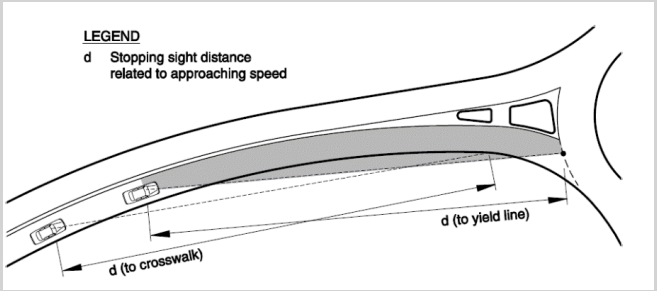
Critical Design Parameters

Sight Distance

- US & UK Guidelines Provide Evaluation Methods for both SSD and ISD, where Greater than Control Values should be Provided
- In German Guidelines Visibility is Considered Fundamental and Drivers must be Constantly Able to Perceive the Presence of other Vehicles, Pedestrians and Bicyclists



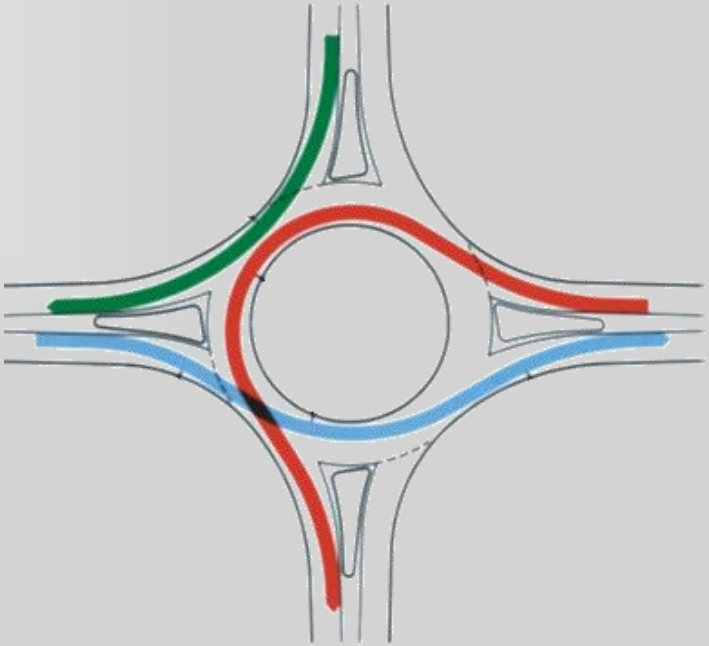




Critical Design Parameters

Entry Path Deflection

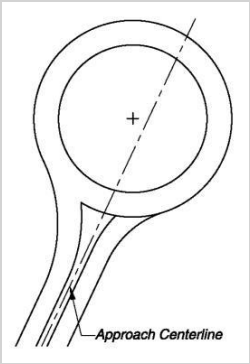
- **US & UK Guidelines**
  - provide adequate entry path deflection through
    - ✓ inscribed circle diameter
    - ✓ circulatory roadway width, entry & exit widths, radii, angles
- **German Guidelines**
  - proper central island size is considered to provide adequate deflection



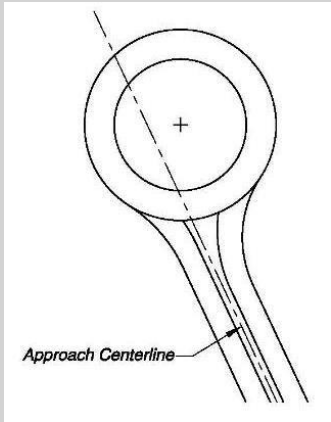
Critical Design Parameters

Approach Alignment

- Radial Alignment of each Leg's Centerline, so Drivers to Negotiate Roundabout at Lower Speeds while Entering and Exiting (Common Design Practice)



- In UK & US the Centerline is Offset (Right or Left) so that Entry Path Deflection Increases and Vehicular Entry Speeds Decrease (Multilane Roundabouts)
  - consequence: higher exit speeds



Critical Design Parameters

Number of Legs and Angle Between

- **US and UK Guidelines Suggest Roundabouts to be Designed with 3 – 4 Approach Legs**
  - double or signalized roundabout if more legs required
- **Angle between Legs**
  - ideally 90º or near
    - ✓ larger angles encourage high negotiating speeds to right-turning flows (left in the UK)
    - ✓ lower angles result to accommodation problems for trucks

Critical Design Parameters

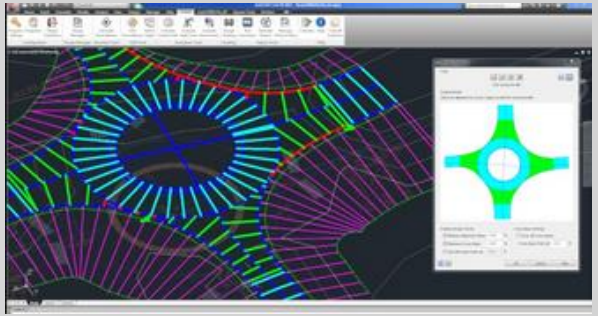
Truck Apron

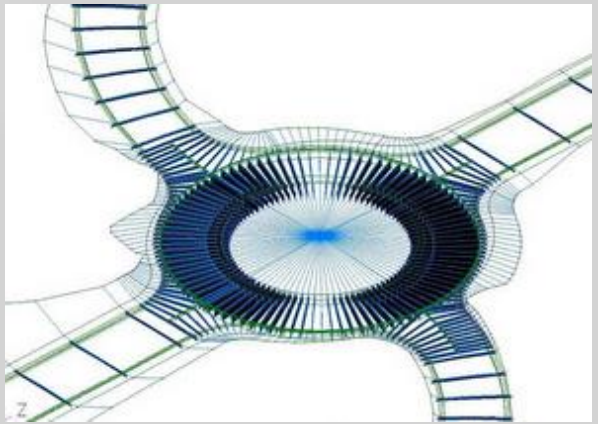
- German Guidelines Utilize Apron Areas Only in Urban Layouts (mostly Single-lane)
- German and US Guidelines Suggest Apron Width Not to Exceed 1/3 of Circulatory Roadway (>1.0m, <4.5m)
- Raised (3cm – 7cm)
- Surface's texture different

Critical Design Parameters

Cross Slope

- Drainage
- Outward Slope
  - US, 2.0%
  - German, 2.5%
- Inward - Outward Slope (UK)
  - ≤2.5%, connection of high speed roads (inward)
  - ≤2.5%, small urban (outward)

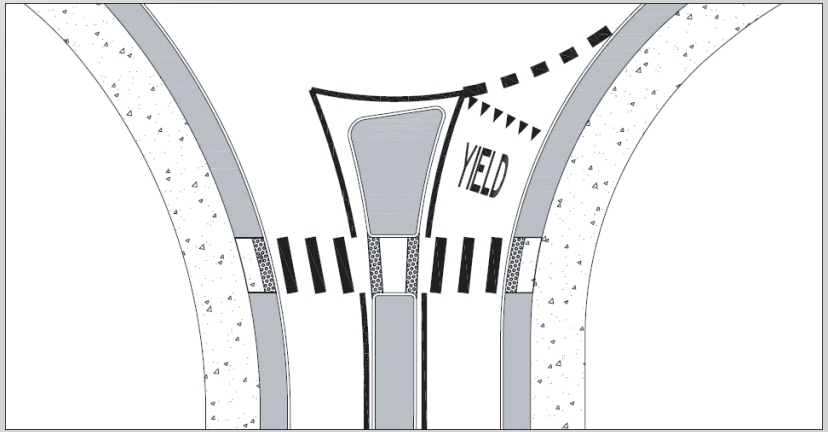




Critical Design Parameters

Splitter Islands (1/2)

- Separate and Guide Entering and Exiting Traffic
- Assist Speed Control
- Forms
  - raised (refuge for pedestrians)
  - painted
  - traversable



Critical Design Parameters

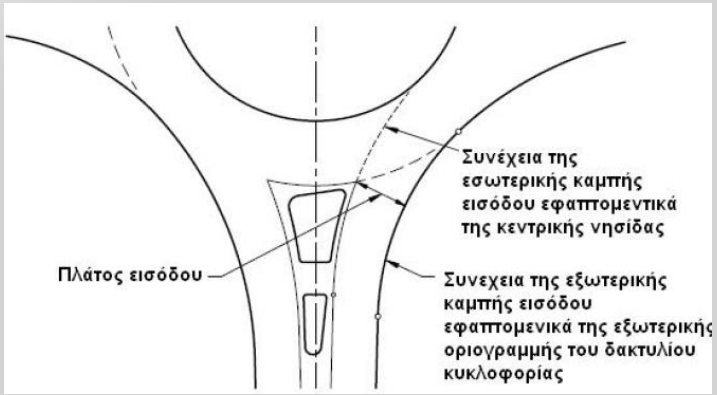
Splitter Islands (2/2)

- **Roundabout Types**
  - **mini**
    - ✓ splitter islands mandatory at every approach (US, UK)
    - ✓ splitter islands optional (German)
  - **single-lane, multilane**
    - ✓ raised– painted (UK, German)
    - ✓ raised (US)
- **Various Design Dimensions**
  - **width, length, location of pedestrian area**

Critical Design Parameters

Entry Width and Flaring (1/2)

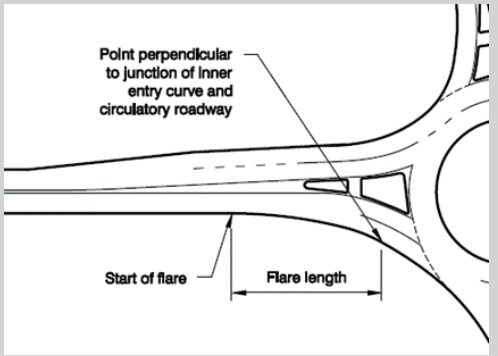
- **Entry Width Dimensions**
  - **UK**
    - ✓ 3.0m – 3.5m / lane, 2+ lane entries
    - ✓ 4.5m, 1 lane entry
  - **US**
    - ✓ 3.7m – 4.6m / lane, 2+ lane entries
    - ✓ 4.2m – 5.5m, 1 lane entry
  - **German**
    - ✓ 3.25m – 3.75m / lane, urban
    - ✓ 3.50m – 4.00m / lane, rural



Critical Design Parameters

Entry Width and Flaring (2/2)

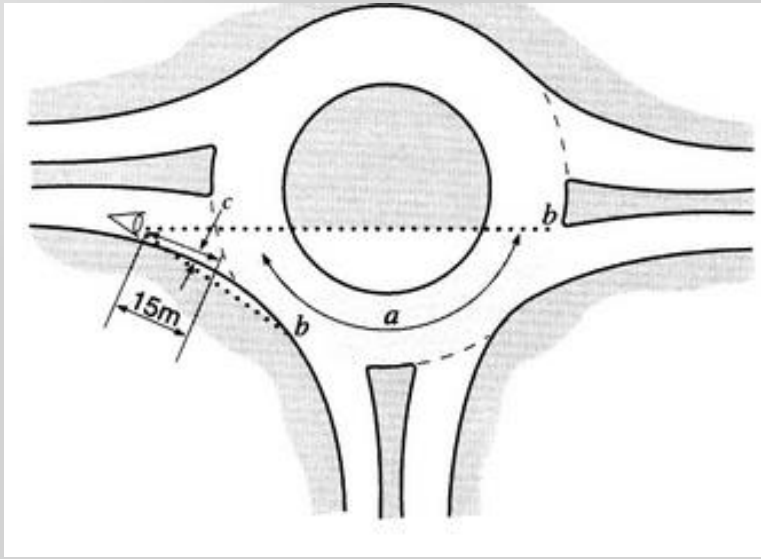
- **Flaring**
  - local widening of entry roadway from approach area to the entry width
    - ✓ additional entry capacity
    - ✓ more efficient accommodation of large vehicles
  - UK
    - ✓ min width 2.5m – existing entry lanes
    - ✓ min length 10m (urban), 50m (rural)
  - US
    - ✓ min width equals existing lane
    - ✓ length maximized within site constraints
    - ✓ vane island design based on design vehicle



Critical Design Parameters

Entry Radius (1/2)

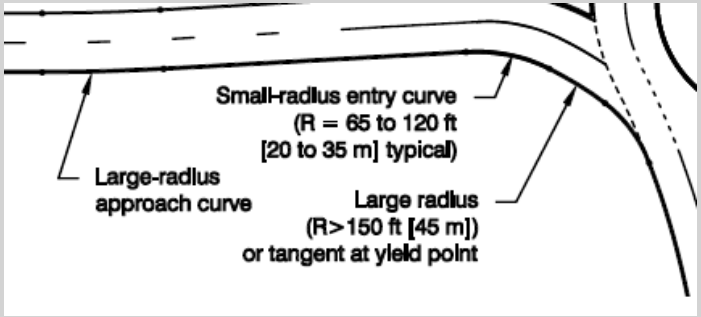
- **Entry Radius Selection**
  - desired speed
  - visibility
  - design vehicle accommodation



Critical Design Parameters

Entry Radius (2/2)

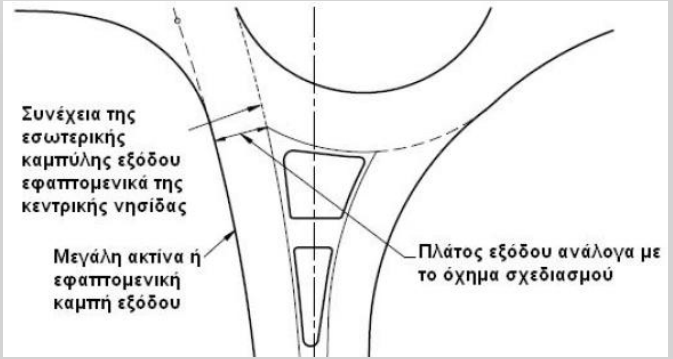
- **US**
  - 15m – 30m single-lane RBs
  - compound curve or tangent at multilane RBs
    - ✓ align vehicles into proper circulatory lane
    - ✓ 6m before circulatory roadway, radius (20m – 35m) followed by a tangent or radius (>45m)
- **German**
  - 8m - 10m, mini RBs
  - 10m – 14m (urban), 14m – 16 (rural) single-lane RBs
  - 12m – 16m (urban), 14m – 16 (rural) Compact 2-lane RBs
- **UK**
  - >10m, mini RBs
  - >15m, single-lane RBs
  - <100m, multi-lane RBs



Critical Design Parameters

Exit Width

- **UK**
  - exit widths equal entry widths, single-lane entries and exits
  - 10.0m – 11.0, 2-lane exit RBs
- **US**
  - exit widths equal entry widths in general
- **German**
  - 3.50m – 4.00m, urban
  - 3.75m – 4.50m, rural



Critical Design Parameters

Exit Radius (1/2)

- **Exit Radius Selection**
  - provide maneuvering sufficiency for design vehicle
  - safe pedestrian crossings (urban)
    - ✓ slow exit path speeds
  - avoid potential conflict between exiting and circulating flow (multilane RBs)
    - ✓ force paths of entering traffic to cross the relevant paths of circulating traffic

Critical Design Parameters

Exit Radius (2/2)

- **UK**
  - exit curvature designed equal to entry
- **US**
  - exit curvature designed greater than entry
  - 30m – 60m single-lane
    - ✓ >250m in certain cases (truck-trailer)
- **German**
  - 8m – 10m, mini RBs
  - 12m – 16m, urban
  - 16m – 18m, rural

Critical Design Parameters

Bypass Lanes

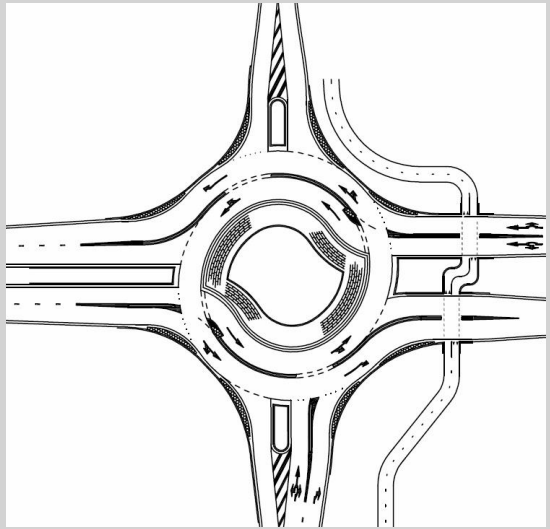
- Right-turn Lanes (Left-turn UK)
  - do not share the same entrance line with the other directions (through and left-turning)
- May Allow a Roundabout to Function Acceptably and Avoid Upgrade
- Considered as the First Step for Increasing Capacity
- Endorsed by All 3 Guidelines

Safety Performance

- Converting a Traditional Intersection to RB may Induce Reduction of Over 70% for Fatal and Severe-injury Accidents
- Low-cost Damage-only Accidents Usually Occur
- Single-lane Rbs seem to be the Safest Type Among All Intersections
- Positive Guidance Through Geometry can have a Positive Impact for Further Decrease in Accident Rates

Special Roundabout Design Concept
Turbo Roundabouts (1/2)

- **Achieves Concurrently**
  High Capacity (Similar to 2-lane RBs),
  and High Safety Performance (Similar to Single-lane RBs)
- **Reduces the Number of Conflicts**
  and Increases Capacity
- **Principles**
  - no lane changing on the RB
    (circulatory lane is defined before entering)
  - no weaving is possible (raised lane dividers)
  - low driving speeds through the RB



Special Roundabout Design Concept
Turbo Roundabouts (2/2)

- **Raised Lane Dividers on Circulatory Roadway**
  - Dutch guidelines suggest
  - German guidelines avoid
    (winter maintenance and motorcycle safety)

- **In Germany, Turbo RBs Suggested Only in Rural Environment (No Pedestrians, No Cyclists)**

Conclusions (1/3)

- **Popular At-grade Intersection Configuration**
  - increased safety performance
  - efficient traffic control
- **Proper Geometric Design Key Issue**
  - determines vehicle speed control
  - achieves consistency in the relative speed between conflicting traffic streams

Conclusions (2/3)

- **Mini Roundabouts**
  - designed under common approach
- **Compact Single-lane Roundabout**
  - safest layout
  - similar approach in terms of design
- **Multilane Roundabouts**
  - marginal differences between both UK and US guidelines and the relevant German
    - ✓ German: no more than two-lane roundabouts, circulatory path with single lane operation for trucks, noticeable design differences at entry - exit areas

Conclusions (3/3)

- **Roundabout Configurations**
  - reduce the number of conflicts
  - eliminate the crossing maneuver
  - accidents mainly involve PDO

- **Research in Safety Impact of Roundabout Conversions**
  - radical improvement in pedestrian accident rates
  - pedestrian safety remains an issue of concern
    - ✓ curb geometry requires special care as to impose slow entrance/exit path speeds