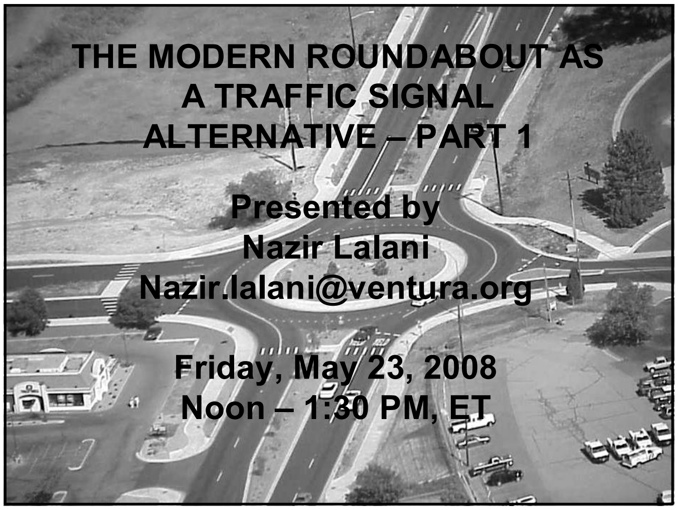


RAPID DEPLOYMENT

- In 1998, Caltrans estimated “fewer than 50 in the US, and about 35,000 in the world
- In 2003, over 80 in Colorado alone
- Over 1,000 estimated in the USA (2005)
- Over 50,000 in the world.
- The UK and France have over 15,000 each

Table 4. Characteristics of modern roundabouts located in the United States (2003).

Characteristics	Number	Percentage of total
Total number	310	
Setting		
• Urban	103	36%
• Suburban	164	58%
• Rural	16	6%
Number of legs		
• 6	4	1%
• 5	16	5%
• 4	197	68%
• 3	70	24%
• 2	4	1%
Number of circulating lanes		
• 3	5	2%
• 2	72	25%
• 1	213	73%
Previous intersection		
• One-way stop	30	19%
• Two-way stop	49	32%
• All-way stop	16	10%
• Signal	14	9%
• None	46	30%
Year created		
• 2000-2003	70	46%
• 1995-1999	70	46%
• 1994 or earlier	12	8%
Geographic location (zip code)		
• Northeast (0,1)	24	8%
• Mid-Atlantic (2)	45	15%
• South, Southeast (3,7)	32	10%
• Midwest (4,5,6)	39	13%
• Mountain West (8)	94	30%
• Pacific Coast (9)	76	25%

Note: Not all characteristics are available for all sites; this explains why the totals for each characteristic add up to less than 310, the total number of roundabouts in the database. For example, setting data are available for 283 of the 310 roundabouts. The percentages cited for urban, suburban, and rural settings add up to 100% of the sample of sites for which data for this characteristic is available. The number of legs and geographic location data do not add to 100% because of rounding.

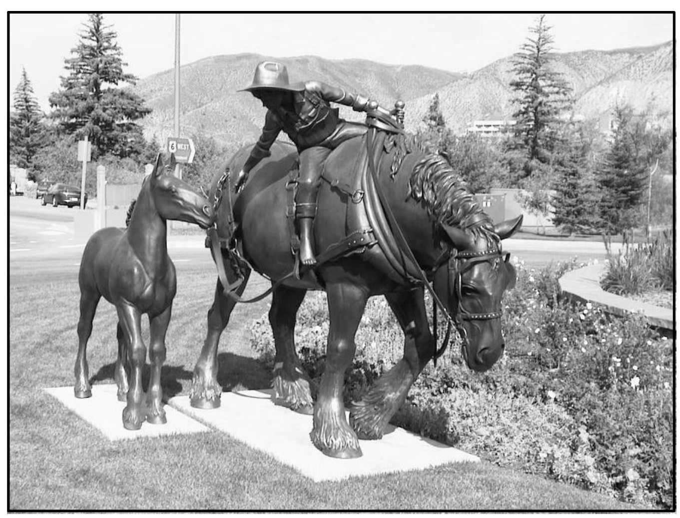
Source: NCHRP 572

Why Roundabouts?

What is the difference between roundabouts and the older circles?

WHY CONSIDER ROUNDABOUTS?

- Safest type of at grade intersection
- No signal equipment, low maintenance costs
- Handles daily changes in directional volumes
- Slows down ALL traffic
- Safe on HIGH SPEED roads
  – Europe avoids rural high speed signals
- Opportunity for Improved aesthetics

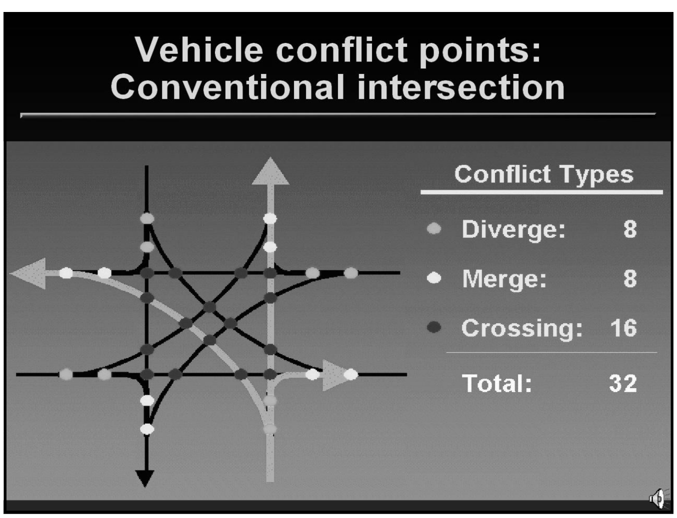


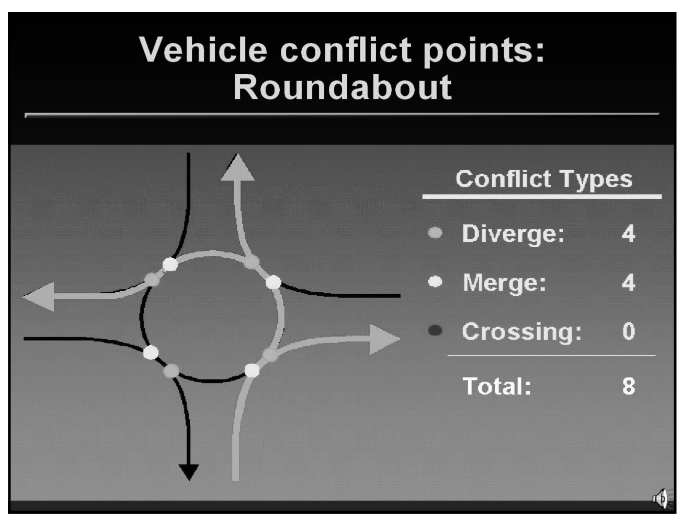
WHY CONSIDER ROUNDABOUTS?

- Unique geometric flexibility
- Fit almost anywhere
- Flexible - easy to modify
- Provide better turning radii for trucks
- Require very small sight distances
- Long life if designed properly

BENEFITS OF ROUNDABOUTS

- Reduced crash frequency/severity for all users
- Pedestrians crossing distances are shorter and require looking in one direction only
- Drivers only make right turns
- Vehicle emissions reduced
- Becoming more cost competitive with increasing signal costs





ROUNDABOUTS APPROPRIATE

- T intersections with stop signs; high delay
- Higher left and right-turning movements
- More than four legs
- Intersections with high crash rates
- High speed four-way intersections
- Future growth resulting in changeable patterns
- Traffic calming purposes

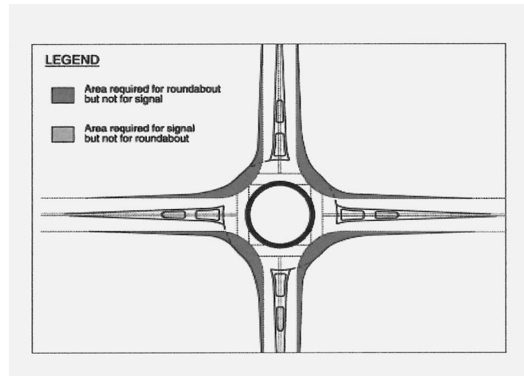
ROUNDABOUTS NOT APPROPRIATE

- Poor geometry because of ROW constraints
- Highly unbalanced flows
- Design cannot handle large/oversize vehicles
- Isolated roundabout in a system of coordinated signals
- Traffic flows leaving roundabout interrupted by downstream traffic control (Signals, RR Xing)

BARRIERS TO ROUNDABOUTS

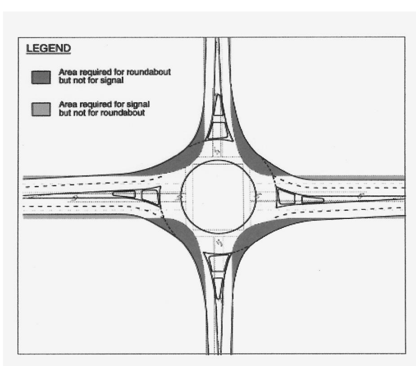
- Flexibility - more ways to get it wrong
- Difficult to design with ROW constraints
- Design process complex/iterative
- At high volumes - can be expensive
- High volume roundabouts more difficult for bicycles & pedestrians
- Super elevation of circular roadway

Right-of-way Impacts



Right of Way – Urban Compact v. Signal

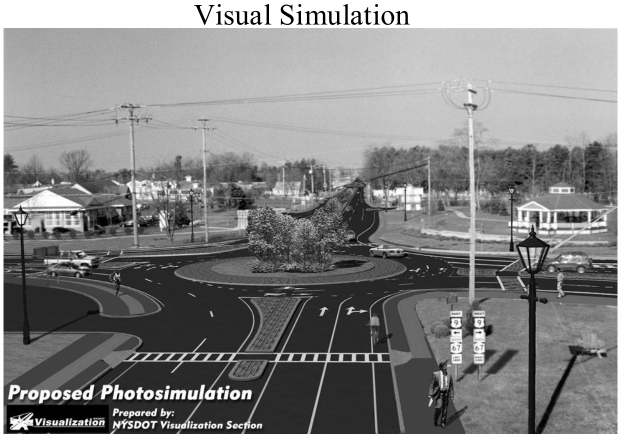
Source: FHWA Roundabout Guide



Right of Way – Urban *Double* Lane v. Signal

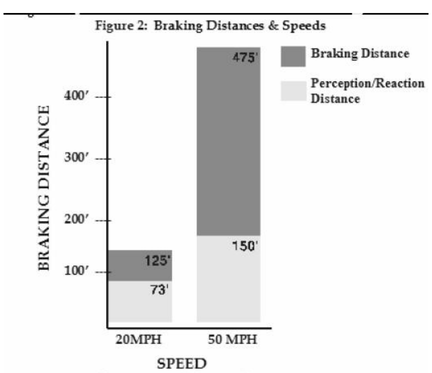
Source: FHWA Roundabout Guide

Visual Simulation



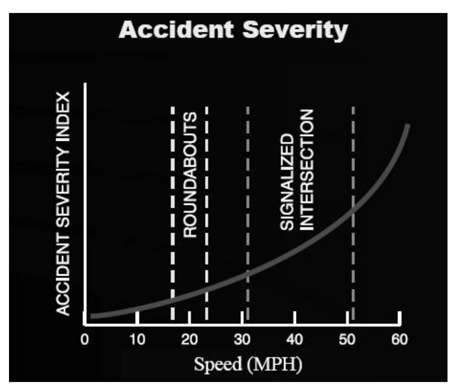
View at Route 9 and Route 67

Why are Roundabout Safer?



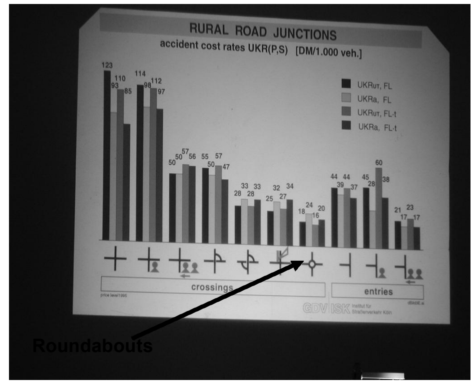
Lower speeds shorter breaking distances

Source: www.roundabouts.us (Scott Ritchie)



Source: www.roundabouts.us (Scott Ritchie)

Vehicle Crash Data



Collision cost rates at rural intersections (Germany)

FINDINGS OF THE INSURANCE INSTITUTE FOR HIGHWAY SAFETY

- Studied 24 intersections
- Crash reduction:
  - 39 % for all crashes
  - 76 % for injury and fatal crashes
  - 90 % for incapacitating injuries and fatal crashes

FINDINGS OF MARYLAND ROUNDABOUT SAFETY STUDY

- Studied 8 locations
- Single lane roundabouts
- 2 years before and after data
- Crash reduction is:
  - 63 % for all crashes
  - 83 % for injury and fatal crashes
  - Mixed results for 2 lane roundabouts

Table 1
Details of the Sample of Roundabout Conversions

Jurisdiction	Year Opened	Control Before*	Single or Multilane	AADT Before	AADT After	Months Before	Months After	Crash Count Before All	Crash Count Before Injury	Crash Count After All	Crash Count After Injury
Anne Arundel County, MD	1995	1	Single	15,345	17,220	56	38	34	9	14	2
Avon, CO	1997	2	Multilane	18,942	30,418	22	19	12	0	3	0
Avon, CO	1997	2	Multilane	13,272	26,691	22	19	11	0	17	1
Avon, CO	1997	6	Multilane	22,030	31,525	22	19	44	4	44	1
Avon, CO	1997	1	Multilane	18,475	27,525	22	19	25	2	13	0
Avon, CO	1997	6	Multilane	18,795	31,476	22	19	48	4	18	0
Bradenton Beach, FL	1992	1	Single	17,000	17,000	36	63	5	0	1	0
Carroll County, MD	1996	1	Single	12,627	15,990	56	28	30	8	4	1
Cecil County, MD	1995	1	Single	7,654	9,293	56	40	20	12	10	1
Fort Walton Beach, FL	1994	2	Single	15,153	17,825	21	24	14	2	4	0
Gainesville, FL	1993	6	Single	5,322	5,322	48	60	4	1	11	3
Gorham, ME	1997	1	Single	11,934	12,205	40	15	20	2	4	0
Hilton Head, SC	1996	1	Single	13,300	16,900	36	46	48	15	9	0
Howard County, MD	1993	1	Single	7,650	8,500	56	68	40	10	14	1
Manchester, VT	1997	1	Single	13,972	15,500	66	31	2	0	1	1
Manhattan, KS	1997	1	Single	4,600	4,600	36	26	9	4	0	0
Montpelier, VT	1995	2	Single	12,627	11,010	29	40	3	1	1	1
Santa Barbara, CA	1992	3	Single	15,600	18,450	55	79	11	0	17	2
Vail, CO	1995	1	Multilane	15,300	17,000	36	47	16	n/a	14	2
Vail, CO	1995	4	Multilane	27,000	30,000	36	47	42	n/a	61	0
Vail, CO	1997	4	Multilane	18,000	20,000	36	21	18	n/a	8	0
Vail, CO	1997	4	Multilane	15,300	17,000	36	21	23	n/a	15	0
Washington County, MD	1996	1	Single	7,185	9,840	56	35	18	6	2	0
West Boca Raton, FL	1994	1	Single	13,469	13,469	31	49	4	1	7	0

*1 = four-legged, one street stopped; 2 = three-legged, one street stopped; 3 = all-way stop; 4 = other unsignalized; 6 = signal

Source: Crash Reductions Following Installation of Roundabouts in the U.S. (IIHS)

Table 2: Maryland Accident Severity Comparison

3 Years Before and After Data for All Roundabouts

Crash Type	Number Of Accidents Before	Number Of Accidents After	Average Accident Cost	Total Accident Cost Before	Total Accident Cost After
Angle	62	8	$125,971	$7,810,202	$1,007,768
Rear-End	6	10	$80,231	$481,386	$802,310
Sideswipe	2	1	$60,819	$121,638	$60,819
Left-turn	11	1	$95,414	$1,049,554	$95,414
Opposite Direction	1	0	$307,289	$307,289	$0
Single Vehicle	3	20	$59,851	$179,553	$1,197,020
TOTALS	**85**	**40**	**3.0**	**$9,949,622**	**$3,163,331**

Source: Accident Reduction With Roundabouts, Myers *RTE High Speed Approach Tables.xls*

Table 3.1: Accident Rate and Accident Cost Rate *(Stuwe 1991)*

	Roundabouts Accident Rate	Roundabouts Accident Cost Rate	Intersections Accident Rate	Intersections Accident Cost Rate
Older roundabouts/intersections with traffic signal	6.58	24.90	3.35	6.49
Newer roundabouts/ intersections with traffic signal	1.24	4.67	1.00	11.96
All roundabouts/all intersections	4.40	16.66	2.76	19.29

Accident Rate = accidents per 1 million vehicles
Accident Cost Rate = Deutsche Marks per 1 million vehicles

Lower crash cost rates at newer roundabouts versus signals

Source: Modern Roundabouts for Oregon (ODOT)

CRASH REDUCTIONS COMPARISIONS (Various Studies)

<u>Roundabout Conversions:</u>

- Crash reduction (stop sign conversion): 60%
- Crash reduction (signal conversion): 37%

<u>Other Safety Mitigation Measures:</u>

- Shoulder widening: 20%
- Rumble strips: 9%
- Adding turn lanes: 25%

Vehicle Crash Types

CRASH CATEGORIES

Entry Crash:
- Rear-end
- Failure to yield right of way
- Other

Circulatory Crash:
- Lane changes
- Fixed object – hit curb
- Other – wrong way circulation

Exit Crash:
- Path overlap
- Fixed object – hit curb
- Other – wrong way circulation

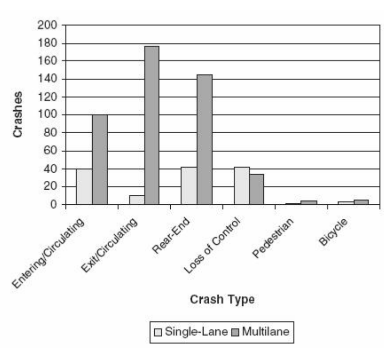
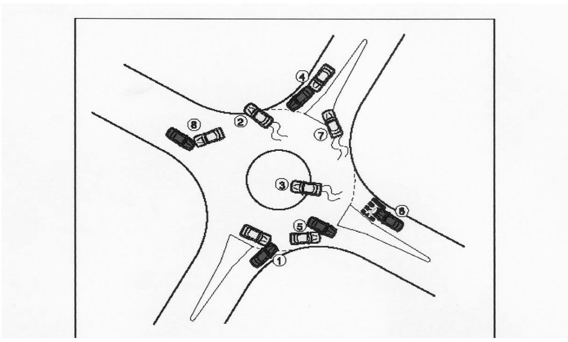


Figure 4. Approach-level crashes by type.

Source: NCHRP 572

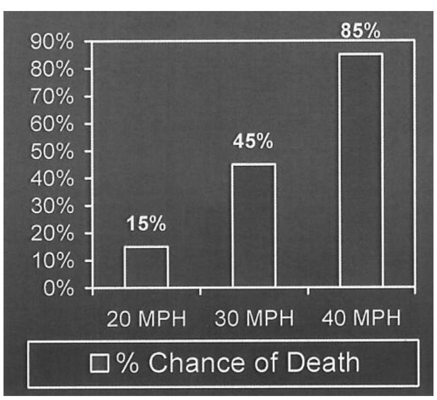
Motorist do go the wrong way



Common crash patterns at a single lane roundabout

Source: FHWA Roundabout Guide

Pedestrian and Bicycle Crash Data



Probability of death v. speed of vehicle

Source: ITE New England Chronicle, September 2003

PEDESTRIAN INJURIES IN THE UK (Injury rates/100 million vehicles)

Mini- Roundabouts	31
Small Roundabouts	33
Conventional 2-Lane	45
Large 2-Lane	72
Traffic Signals	67

US ROUNDABOUTS WITH HIGH PEDESTRIAN VOLUMES (Injury rates per year)

Clearwater Beach (1999):

- Pedestrians (Before) 1.6
- Pedestrians (After) 0.0
- Bikes (Before) 2.0
- Bikes After 0.0

Towson, Maryland (1998):

- Pedestrians (Before) 0.4
- Pedestrians (After) 0.2

Roundabout Capacity

TRAFFIC CAPACITY

ADT capacity approximate capacity:

- ✓Single-lane roundabout: 25,000 vehicles per day
- ✓Double-lane roundabout: up to 50,000 vehicles per day

Hourly volume capacity approximate capacity:

≈ 2,000 VPH single lane

≈ 4,000 VPH multi-lane

≈ 6,000 VPH three-lanes

≈ 8,000 VPH four-lanes

Table 1. Typical Inscribed Circle Diameters and Daily Service Volumes

Roundabout Type	Typical Inscribed Circle Diameter[1]	Typical Daily Service Volume[2] (vpd) 4-leg roundabouts
Urban Single-Lane	100 -160 ft **(30 – 50 m)**	less than 25,000
Urban Multilane (2-lane entry)	150 - 200 ft **(45 – 60 m)**	25,000 to 55,000
Urban Multilane (3 or 4-lane entry)	180 - 330 ft **(55 – 100 m)**	55,000 to 80,000
Rural Single-Lane	115 -180 ft **(35 – 55 m)**	less than 25,000
Rural Multilane (2-lane entry)	180 - 230 ft **(55 – 70 m)**	25,000 to 55,000
Rural Multilane (3-lane entry)	180 - 330 ft **(55 – 100 m)**	55,000 to 70,000

[1]The diameters provided are for general guidance.

[2]Capacities vary substantially depending on entering traffic volumes and turning movements (circulating flow).

Source: Facilities Development Manual (WSDOT)

PRIMARY MODELS USED IN US FOR ROUNDABOUT ANALYSIS

- RODEL - Empirical ROundabout DELay
  - (Assessment of Roundabout CApacity and DelaY)
- SIDRA – Analytical (Gap theory)
- VISSIM, Paramics – Simulation (Gap theory)

Evaluation:

- Each is different, results vary significantly
- Each is useful, none are perfect
- None are all-encompassing
- No one agrees as to which is most accurate

MODEL DIFFERENCES

- GAP THEORY
  - Assumes a single roundabout capacity mechanism
  - Availability of gaps in the circulating traffic
- EMPIRICAL
  - Empirical Method captures all capacity mechanisms (gap availability and design)
  - Field studies determined about five significant capacity mechanisms
  - Field data collected from roundabouts operating at capacity limits

RODEL (DOS Based)

- RODEL helps determine the optimum geometry dimensions
- Focus then can be on key strategic aspects, like the best location of the circle and the approach angles of the legs
- RODEL allows the selection of the level of V/C confidence. Other models use a confidence level of 50 percent (ARCADY, HCS, TRANSYT)
- Strongly relates capacity to detailed geometry

GAP (SIDRA)

- Gap models - adequately predict roundabout capacity within certain ranges of traffic flows
- Outside these ranges gap models can over-predict capacity at low flows - under-predict capacity at high
- At low flows – drivers often react to enter a major traffic stream more slowly
- At high flows - “gap-forcing” and “priority reversal” take place - not explained well by conventional gap acceptance theory

VISSIM

- VISSIM is a microscopic, behavior-based multi-purpose traffic simulation program
- Complex traffic conditions are visualized at a level of detail providing realistic traffic models
- Link/connector network structure
- Specify gap acceptance parameters by lane for each approach
- Simulation level depends on Level of program purchased

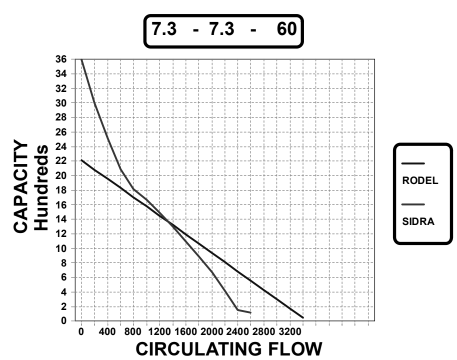
SYSTEM CONSIDERATIONS: USE VISSIM IF YOU NEED TO MODEL

- Traffic Signals at Roundabouts
- Railroad Crossings
- Transit crossings
- Roundabout Spacing
- Roundabouts in an Arterial Network
- Microscopic Simulation
- Can take tweaking to realistically simulate an individual roundabout

Roundabout close to a traffic signal

RODEL & SIDRA

7.3m Entry 60m ICD



PRACTICAL CONSEQUENCES OF POOR MODELING

- **Low circulating flows = Under-design (SLR)**
- **High circulating flows = Over-design (MLR)**
- **Major road is under-designed - early congestion**
- **Minor road is over-designed - less safe geometry**
- **Abandoning the roundabout option - ROW constraints**
- **Over design produces larger less safe geometry**

Note: Lower circulating speeds can provide greater capacity

ANALYSIS METHODS

- Macroscopic Models (Isolated):

  Analyze vehicle flows

  Methods include RODEL and SIDRA

- Microscopic Models (System):

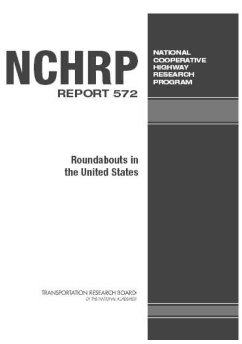
  Analyze individual vehicles and drivers

  Methods include VISSIM, SimTraffic, Paramics

ROUNDBOUT CAPACITY SOFTWARE

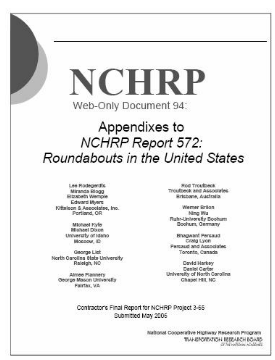
- **NCHRP 572:**

  Both methods overestimate capacity for U.S. conditions. Chapter 3 discussed models calibration for US conditions



http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_572.pdf

APPENDIX TO REPORT 572



NCHRP

Web-Only Document 94:

Appendixes to
NCHRP Report 572:
Roundabouts in the United States

Lee Rodegerdts
Miranda Blogg
Elizabeth Wemple
Edward Myers
Kittelson & Associates, Inc.
Portland, OR

Michael Kyte
Michael Dixon
University of Idaho
Moscow, ID

George List
North Carolina State University
Raleigh, NC

Aimee Flannery
George Mason University
Fairfax, VA

Rod Troutbeck
Troutbeck and Associates
Brisbane, Australia

Werner Brilon
Ning Wu
Ruhr-University Bochum
Bochum, Germany

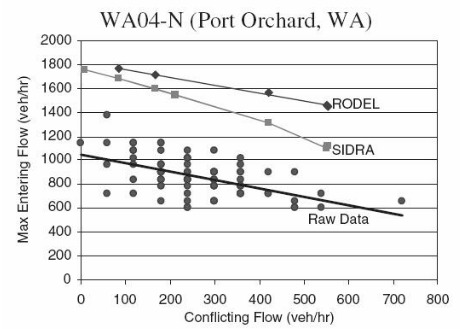
Bhagwant Persaud
Craig Lyon
Persaud and Associates
Toronto, Canada

David Harkey
Daniel Carter
University of North Carolina
Chapel Hill, NC

Contractor's Final Report for NCHRP Project 3-65
Submitted May 2006

National Cooperative Highway Research Program
TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w94.pdf

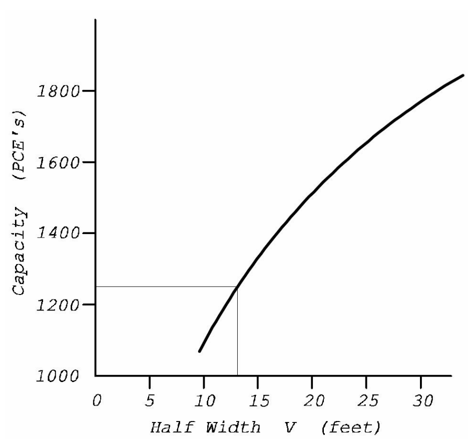


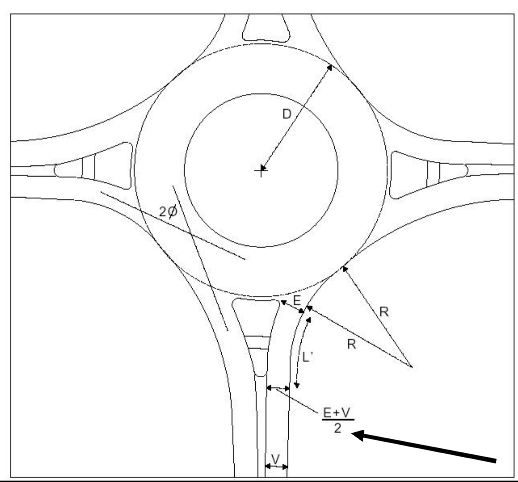
Source: NCHRP 572

SIX KEY GEOMETRIC PARAMETERS

- Entry Width, E.
- Flare Length, L'.
- Half Width, V.
- Entry Radius, R.
- Entry Angle, ø.
- Inscribed Circle Diameter, D/ICD.

The Half-Width 'V'

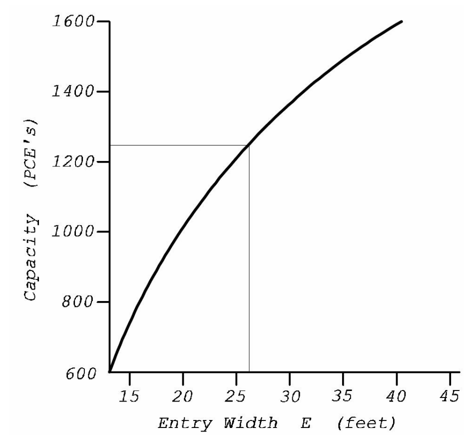


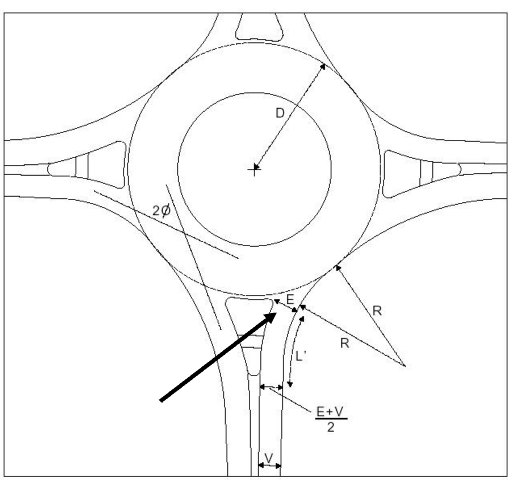


THE HALF-WIDTH ‘V’

- Distance curb face - curb face (or center line)
- Capacity is very sensitive to ‘V’
- V must be effective - no parking
- V is crash neutral - does not increase crashes
- V is always known before a design

Entry Width - E

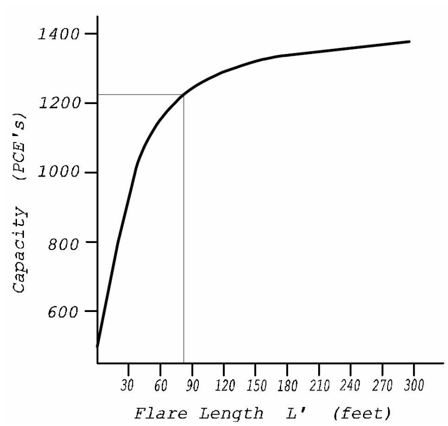


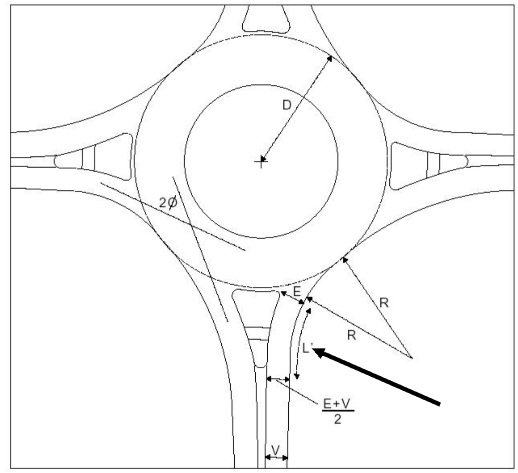


ENTRY WIDTH - E

- Measured curb face - curb face
- Increasing E sharply increases capacity
- E is so powerful it can ‘take over’ designer
- BUT increasing E increases crashes
- Increase E in very small steps
- Use other geometrics to increase capacity
- Large E impacts most all other geometrics – path, R, Phi, next exit, ROW

Flare Length - L’





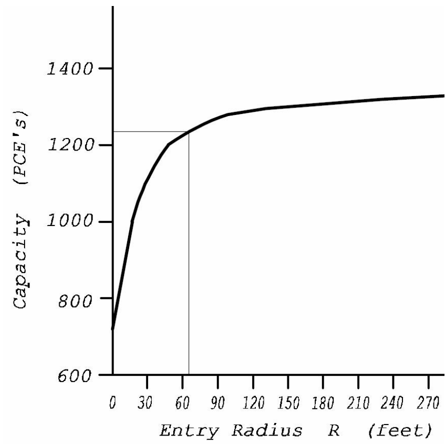
FLARE LENGTH - L’

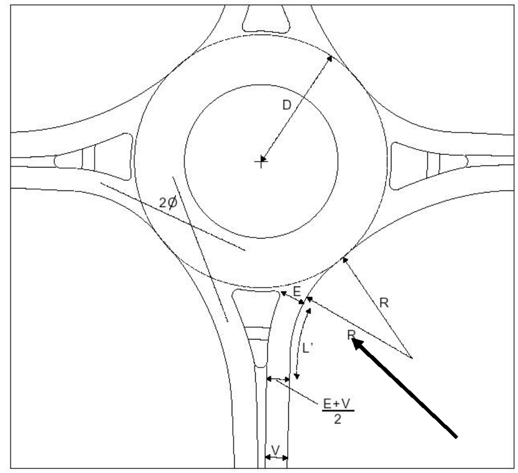
- Capacity is also very sensitive to L’
- Flare length is crash neutral
- L’ usually between 15 - 325 ft
- 325 ft L’ ~= 95% of full parallel capacity
- Even 15 ft L’ can give good capacity increase
- Long L’ requires more ROW

E, AND L’ ARE POWERFULLY RELATED

- E and L’ and V are related
- V is known and fixed
- E and L’ can be varied by designer
- Increasing L’ increases capacity
- Increasing E can greatly increase
- Combined effect is remarkably large
- Small changes = large capacity change

Entry Radius - R

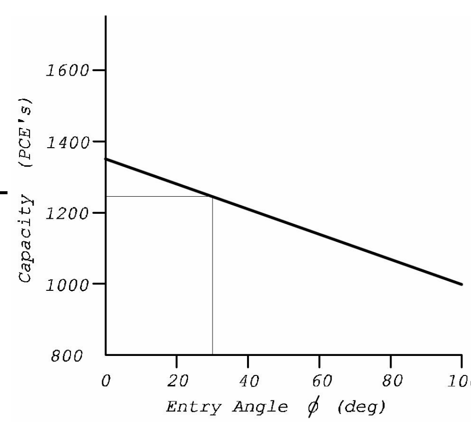


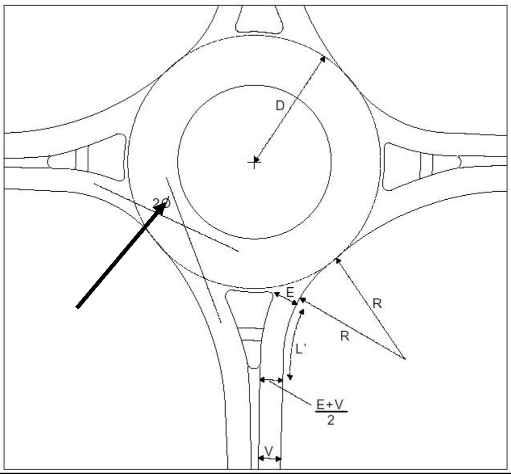


ENTRY RADIUS - R

- Increase R above 65' = small capacity increase
- Capacity drops with increasing severity below 50'
- Gap Models do not include R
  - R made small to reduce entry speeds
  - No capacity reduction predicted
- Small R can cause problems on MLRs
  - On MLRs - R should not be less than ~ 50 ft

Entry Angle – 'Phi'

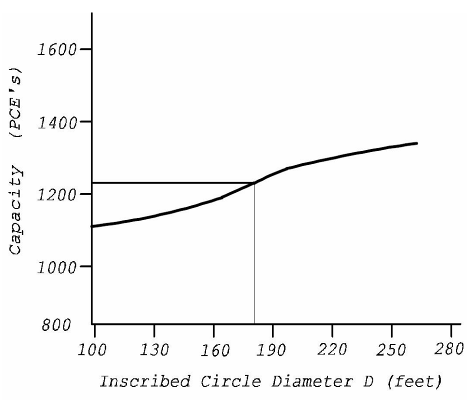


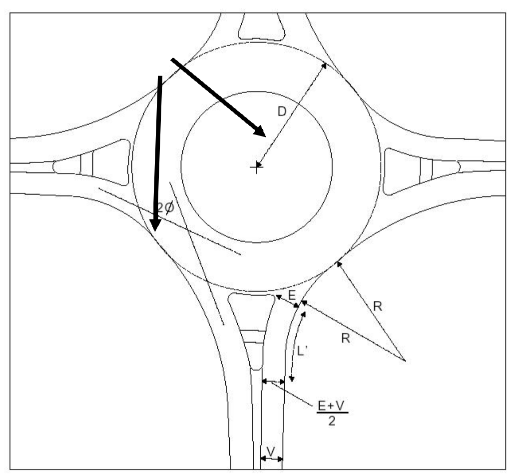


ENTRY ANGLE - PHI

- Mean angle between entry and circulating traffic
- Phi is tricky to measure – easy to get it wrong
- The smaller Phi - larger the capacity
  - Phi = 0 = On Ramp type merge
- By itself - small Phi allows fast entry speeds
  - Phi can safely be made smaller if other geometrics are used to control entry speed
- Very Small Phi can cause severe neck turning
- 20 > Phi < 40 degrees is typical

Inscribed Circle Diameter 'D' (ICD)





INSCRIBED CIRCLE DIAMETER 'D'

- Small capacity increase at low circulating flows
  - Gap is controlling capacity
- Large capacity increase at high circulating flows
- Avoid very large D - fast circulating speeds
- Reduce D and increase E and L' = more capacity
- Smaller D avoids 'reverse curves' at entry & exit
- Minimum D set by sum of entry and exit widths

Table 70. Relationship between crashes and geometry, sorted on crash rates.

	Crash Frequency (crashes/yr)	Crash Rate (crashes/MEV)	Average Number of Lanes in Group	Average Inscribed Circle Diameter	Average Daily Traffic (veh/day)	Average Number of Legs in Group
Total Dataset	4.95	0.75	1.39	133 ft (41 m)	16,606	3.89
First Ten	0.02	0.00	1.20	95 ft (29 m)	9,295	3.70
First Thirty	0.59	0.10	1.23	123 ft (37 m)	14,961	3.73
Bottom Thirty	11.75	1.69	1.70	165 ft (50 m)	20,186	4.07
Bottom Ten	18.51	3.03	1.90	150 ft (46 m)	16,734	4.20

Legend: MEV = million entering vehicles; veh = vehicles

Crash frequency increases with increasing inscribed circle diameter (D)

Source: NCHRP 572

Eliminating Left-Turns at a Signalized Intersection With The Use of Nearby Roundabouts

May 30, 2007

Authored by

Benjamin T. Waldman, P.E., PTOE
LSC Transportation Consultants, Inc.,
1889 York Street
Denver, CO 80206
Phone: 303-333-1105

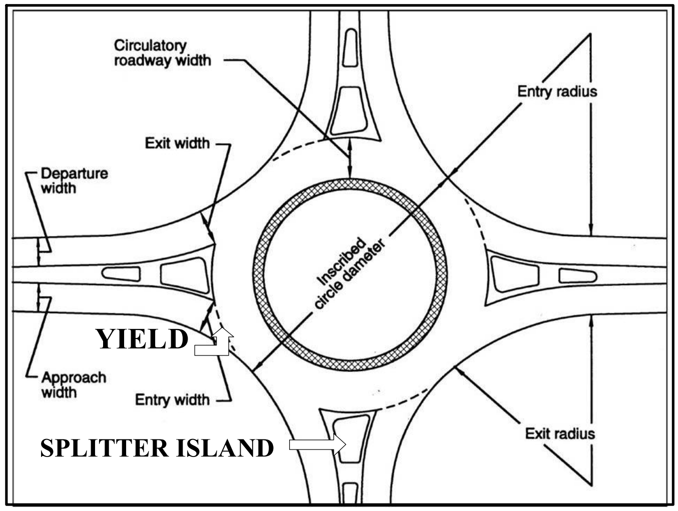
Co-Authored by

Alex J. Ariniello, P.E., PTOE
SM Alam, P.E.
LSC Transportation Consultants, Inc.,
1889 York Street
Denver, CO 80206
Phone: 303-333-1105

Roundabout Design

KEY FEATURES

- Entering vehicles must yield
- Use median 'splitter' deflection to force lower speeds before entering roundabout
- Vehicles circulate in counter-clockwise direction at 15 - 25 mph
- Increasing the angle between arms sharply reduces crash frequency
- Increases in the entry width produce significant increases in capacity and crash frequency
- Crash frequency increases with larger circulating width – single lane~15-18' (with truck apron)

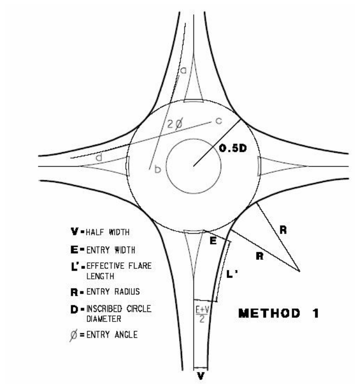


DESIGN PROCESS

- No Stopping Sight Distance - NO ROUNDABOUT
- Design process can find a solution to the SSD
- Begin by evaluating, checking and learning about the intersection
- Most start by drawing - not recommended
- Collect and review traffic data
- Obtain existing as built drawings
- Review traffic data

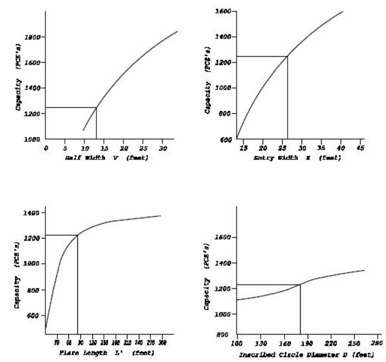
REVIEW TRAFFIC DATA

- Obtain hourly turning traffic volumes, cannot be estimated from daily volumes
- BOTH peaks are essential, and any other peaks
- Check approach/departure road capacity and volumes
- Look for other data – peds, trucks, seasonal activities -
- May need a mid-year point of data to determine need to go from single to multi-lane?



Geometric Design Parameters

Source: Facilities Development Manual (WSDOT)



V: Upstream Approach Width

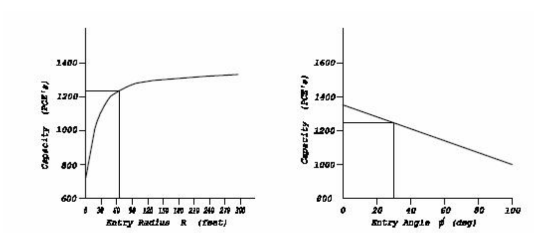
E: Entry Width

L: Flare Length

D: Inscribed Circle Diameter

Capacity impact of geometric design parameters

Source: Rodel Software Manual (FLDOT)



R: Entry Radius
Phi: Entry Angle

Capacity impacts of geometric design parameters

Source: Rodel Software Manual (FLDOT)

USE COMPUTER MODEL RESULTS TO DRAW A ROUGH LAYOUT

- Start by drawing VERY approximately
- Refine and polish geometry later.
- Best done BY HAND
- Especially on difficult designs
  - High volumes and ROW constraints
  - Skew Approach Roads
  - More than 4 legs
- Or SKETCH very roughly with CAD
- Forget about tangents etc at this stage.

Table 2. Default Geometric Parameters[A] for Both Urban & Rural Roundabouts

Geometric Parameter	Single-Lane Entry	Dual-Lane Entry	Triple-Lane Entry
1 Half width [B]	Travel lane width approaching the roundabout prior to any flared section.		
2 Entry width [B]	Face of curb to face of curb shortest distance at yield point.		
3 Effective Flare length [B]	15-330 ft **(5-100 m)** if needed.		
4 Inscribed diameter [C]	130 ft **(40 m)**	160 ft **(50 m)**	250 ft **(75 m)**
5 Entry Radius	65 ft **(20 m)**	80 ft **(25 m)**	100 ft **(30 m)**
6 Entry angle	30 Degrees		
7 Circulating roadway width	20-25 ft **(6-7 m)** (truck apron may be needed)	30 ft **(10 m)** (truck apron not needed)	45 ft **(14 m)** (truck apron not needed)
8 Exit radius	50-65 ft **(15-20 m)**	65-100 ft **(20-30 m)**	100-130 ft **(30-40 m)**

[A] At this time RODEL works only with metric values.
[B] High influence on capacity. [C] Low influence on capacity.

Design is iterative process beginning with six design parameters V, E, D, L, R and Angle

Source: Facilities Development Manual (WSDOT)

	Design Element	Mini (1)	Urban (2) Compact	Urban Single-Lane	Urban Double-Lane	Rural Single-Lane	Rural Double-Lane
General	Number of Lanes	1	1	1	2	1	2
General	Typical max. (3) ADT	12,000	15,000	20,000	40,000	20,000	40,000
General	Splitter Island Treatment	Painted, raised if possible	Raised	Raised	Raised	Raised extended	Raised extended
General	Max. Design(4) Vehicle	SU	SU/BUS	WB-50	WB-50	WB-67	WB-67
Circulating	Inscribed Circle Diameter	45'-80'	80'-100'(5)	100'-130'(6)	150'-180'	115'-130'(6)	180'-200'
Circulating	Circulating Roadway Design Speed	15-18 mph	16-20 mph	20-25 mph	22-28 mph	22-27 mph	25-30 mph
Circulating	Circulating Roadway Width	14'-19'	14'-19'	14'-19'	29'-32'	14'-19'	29'-32'
Entry	Max. Entry Design Speed	15 mph	15 mph	20 mph	25 mph	25 mph	30 mph
Entry	Entry Radius	25'-45'	25'(7)-100'	35'(7)-100'	100'-200'	40'(7)-120'	130'-260'
Entry	Entry Lane Widths	14'-16'	14'-16'	14'-16'	25'-28'	14'-16'	25'-28'

Roundabout design characteristics

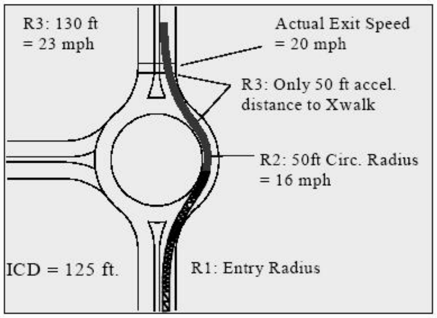
Source: Chapter 9, Design Manual, WADOT

FINALLY - DRAW ACCURATELY

- The design is done – problems largely solved
- Now refine and draw exactly (CAD)
- Check entry radii and adjust
- Check and adjust exit radii
- Accurately draw in context of the rough solution
- If details are drawn first (bottom up design)
  - Parts may be OK but the whole is wrong
- Bottom-up designs look stiff and formal
- Designs should have a flowing, organic look

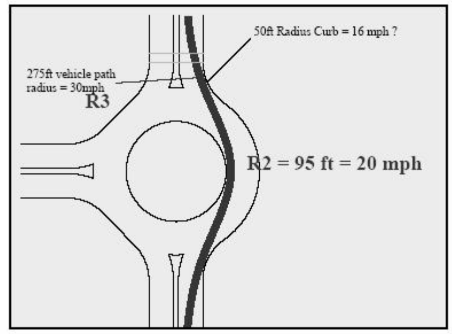
FINAL CHECK

- Leave design for about 3-4 days
- Review it afresh – things become visible
- Horizontal is now totally FINSHED
- Only now do the vertical design
- Occasionally some horizontal / vertical interaction
- Some horizontal revision may be needed
- Signing and striping
- Refine for multimodal users
- Consider peer review



R 1 and R 2 govern exit speed and not R 3 due to short acceleration distance shown in red

Source: Alternate Design Methods for Pedestrian Safety at Roundabout Entries and Exits (Baranowski)



At multilane roundabouts (MLR), a tight R3 exit radius will cause exit overlap and crashes – R1 and R 2 are more important

There are many elements

- **Entry Width**
- **Entry Flare**
- **Entry Angle**
- **Entry Radius**
- **Entry Deflection**
- **Entry Path Curvature**
- **Entry Path Overlap**
- **Entry Speeds**
- **Fast Path Speeds**
- **Speed Consistency**
- **Sight Distance**
- **Exit Path Overlap**
- **Entry & Circulating Visibility**
- **Splitter Island Design**
- **Exit Lanes and Geometry**
- **Pedestrian Crosswalks**
- **Maneuverability of trucks**
- **Vertical Design Parameters**

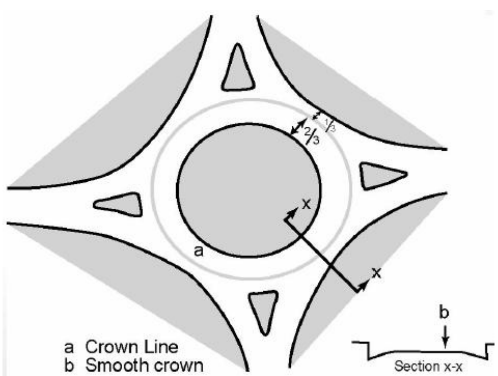
DESIGN GUIDANCE

- Approach grades ~ 3%
- Entry grades < 2%
- Exit grades < 4%
- Circulatory roadway ~ 1.0 to 1.2 x entry width (for single lane, try 18' with truck apron)
- Two-lane entries into single lane circulatory roadway not recommended
- Splitter islands are essential

The circulatory roadway should not be wider than 18 feet excluding the truck apron

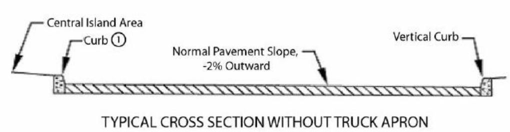
DESIGN GUIDANCE

- **Don't offset approach alignment from roundabout center**
- **Negative super elevation (-2%) for circulatory roadway to handle drainage to avoid hydroplaning**
- **Adequate sight distance must be provided**
- **Curbs are necessary**
- **Right-turn by passes only at low pedestrian locations**



Grade break has caused truck problems

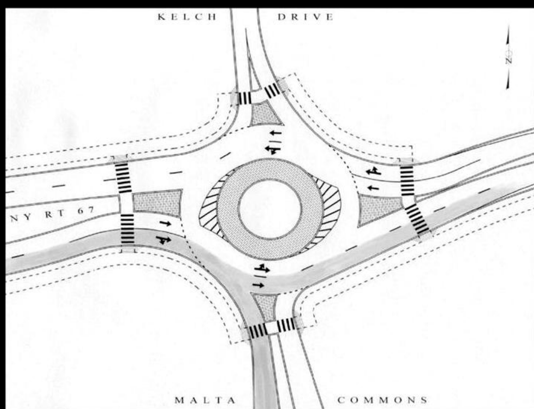
Source: Janet Kennedy, Transport Research Laboratory, UK



Cross section of circulatory roadway

Source: Caltrans Design Information Bulletin 80-01: Roundabouts

Proper Right Lane Movements



Proper Left Lane Movements

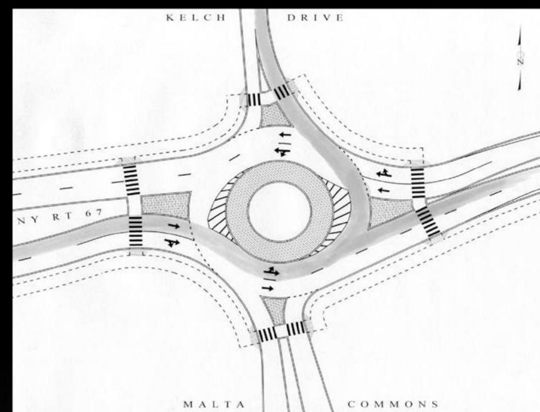
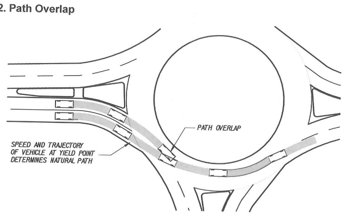
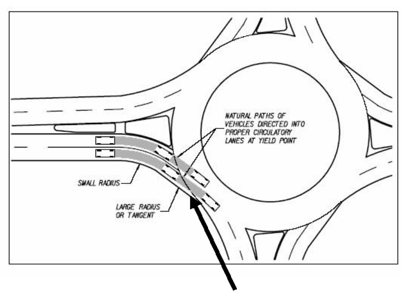


Figure 2. Path Overlap



Path overlap is a problem at MLRs

Source: Facilities Development Manual (WSDOT)



Greater entry deflection by increasing ICD (caution: larger ICD will increase circulatory speeds – not good for pedestrians)

Source: Facilities Development Manual (WSDOT)

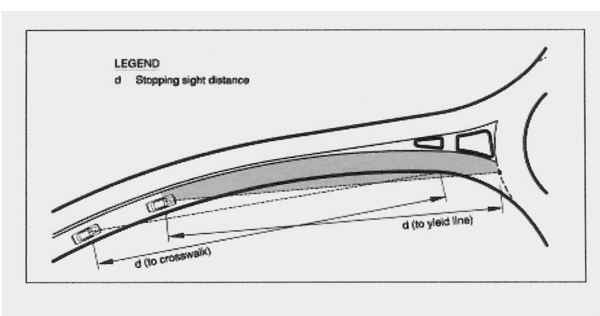
Min. distance to nearest access (distance from splitter island)	600’ on principal arterial 300’ on minor arterial 100’ on all collectors 30’ on local access

Minimum distance to nearest access

Source: Roundabout Design Standards
- City of Colorado Springs

ROUNDABOUT SAFETY REVIEW

- ✓ Is sight distance adequate at all points?
- ✓Signing easily understood?
- ✓Consistency among signs/markings to clarify approach?
- ✓Appropriate warning signs at correct distance from hazards?
- ✓Does landscaping or other signs obscure visibility?
- ✓Are the signs appropriate for the design speed?
- ✓Do markings clearly define routes for lane designations?
- ✓Are markings and sign letter heights adequate?



Stopping Sight Distance

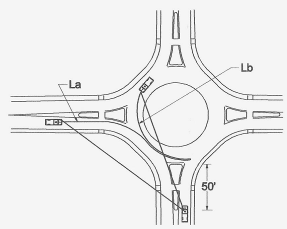
Source: FHWA Roundabout Guide

Table 5.2: Approach Sight Distance (ASD) *(Maryland)*

Approach Speed		Stopping Distance	
(mph)	(km/h)	(ft)	(m)
25	(40)	98	(30)
31	(50)	131	(40)
37	(60)	180	(60)
43	(70)	230	(70)
50	(80)	344	(110)
56	(90)	426	(140)
62	(100)	525	(170)
68	(110)	623	(200)
75	(120)	754	(250)

*measured 4.0 ft to zero

Source: Modern Roundabouts for Oregon (ODOT)

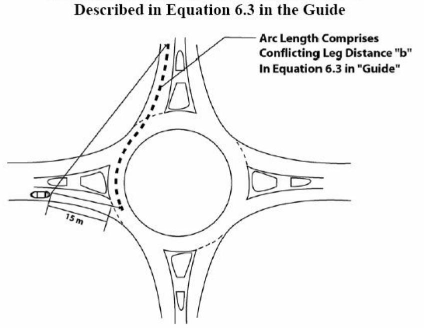


Speed (mph)	Gap Acceptance Length (min), L (ft)
15	115
20	150
25	185
30	225
35	260

Source: WADOT Design Manual – Chapter 915

Landscaping enhancement features obstructing sight distance

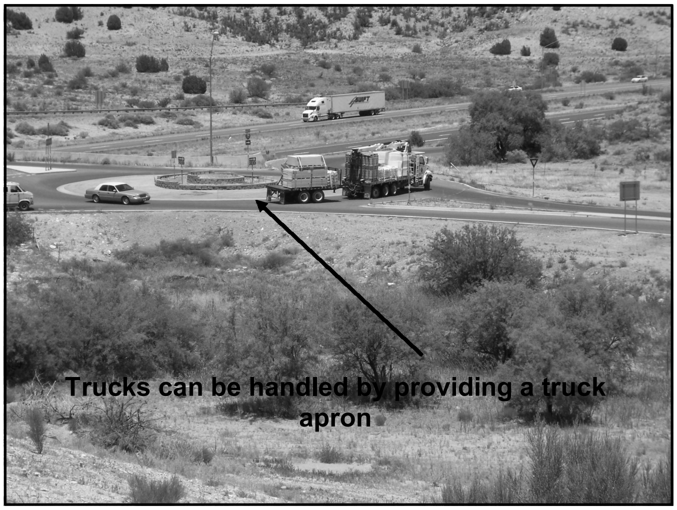
Figure 2
Entering Stream Conflicting Leg Distance "b"
Described in Equation 6.3 in the Guide



Source: Caltrans Design Information Bulletin 80-01:

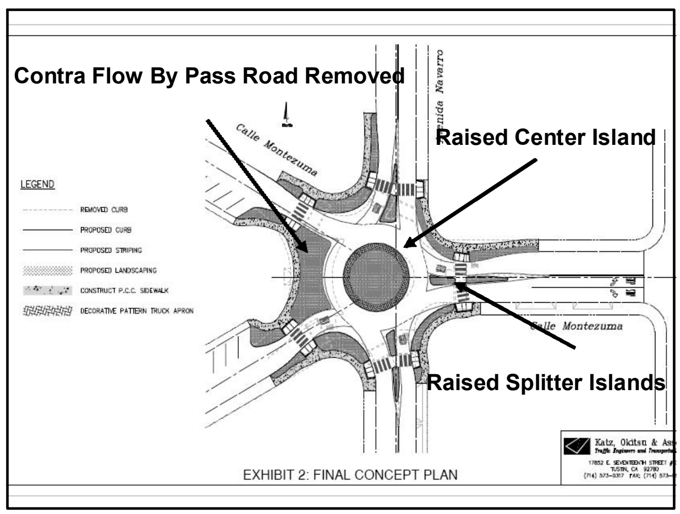
QUICK LIST

- Collect information and data
- Run models
- Sketch, find circle location and sketch approaches
- CAD a concept. Recheck/test
- Public outreach
- Go to 30%, retest, ROW and Utilities
- Public outreach
- Go to 60%



CASE STUDY

What is wrong here ?




QUESTIONS