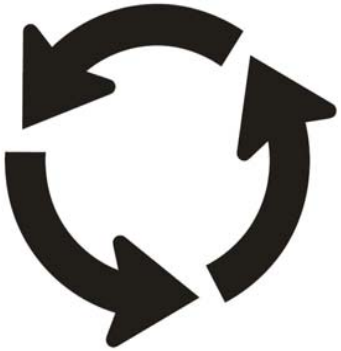
Modern Roundabouts:
A Safer Choice



ODOT Traffic Engineering Conference

Wilsonville, OR

June 7, 2011

Photo: ODOT

Oregon Department of Transportation

KITTELSON & ASSOCIATES, INC.
TRANSPORTATION ENGINEERING/PLANNING

Presentation Outline

- **Characteristics**
- **Some History**
- **Where are they being used?**
- **Benefits**
- **Freight Considerations**

What is not a modern roundabout?

Rotary

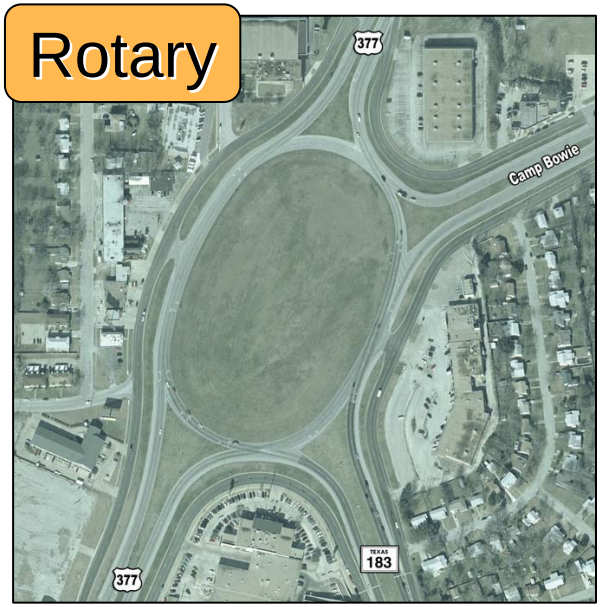


Photo: City of Fort Worth, TX

Traffic Circle

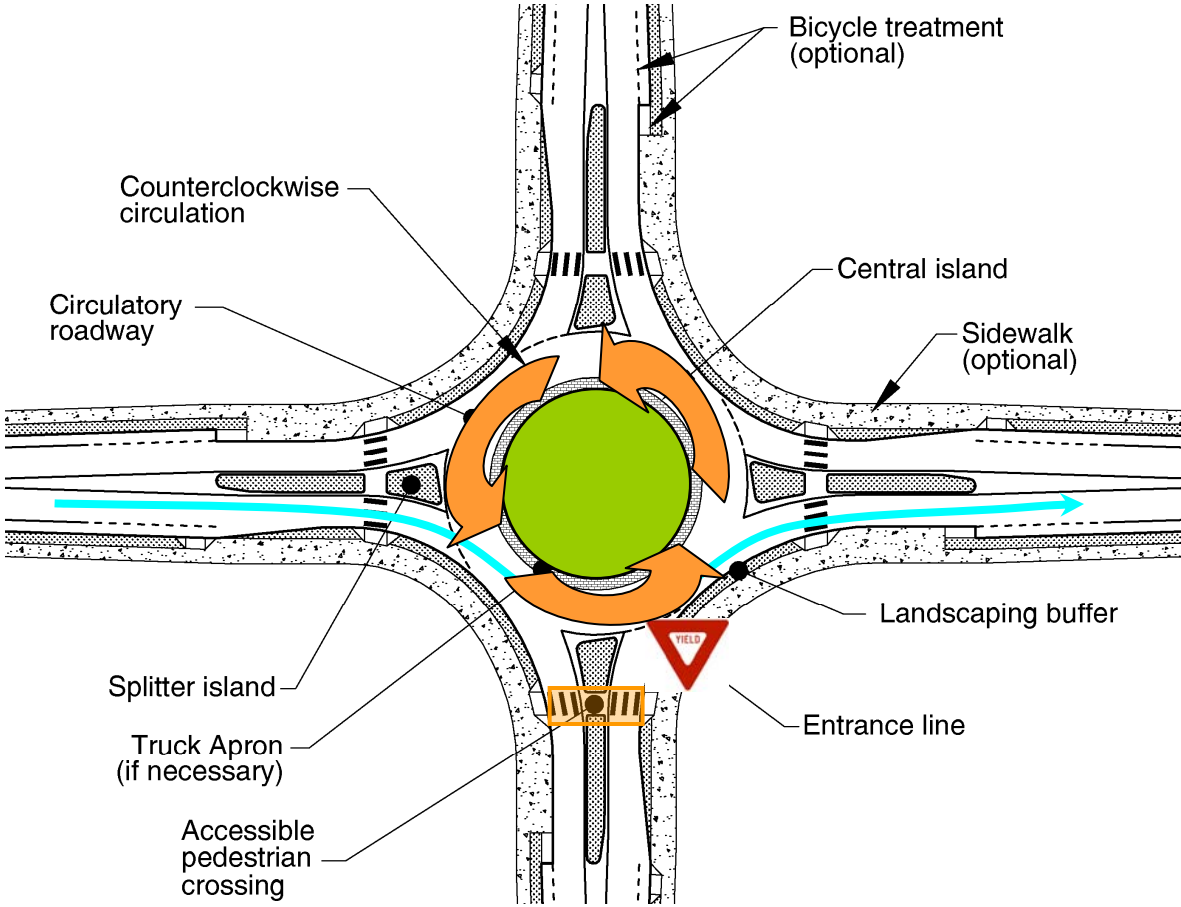
Photo: Google Maps

Neighborhood Traffic Circle

Photo: Lee Rodegerdts

What is a modern roundabout?

- **YIELD control on entry**
  - Priority to circulating vehicles
- **Slow, consistent speeds**
- **Landscaping**
- **Pedestrian access & crossing**
- **No Parking**
- **Direction of circulation**
  - Channelization



Conversion of Rotary to Roundabout: Kingston, NY

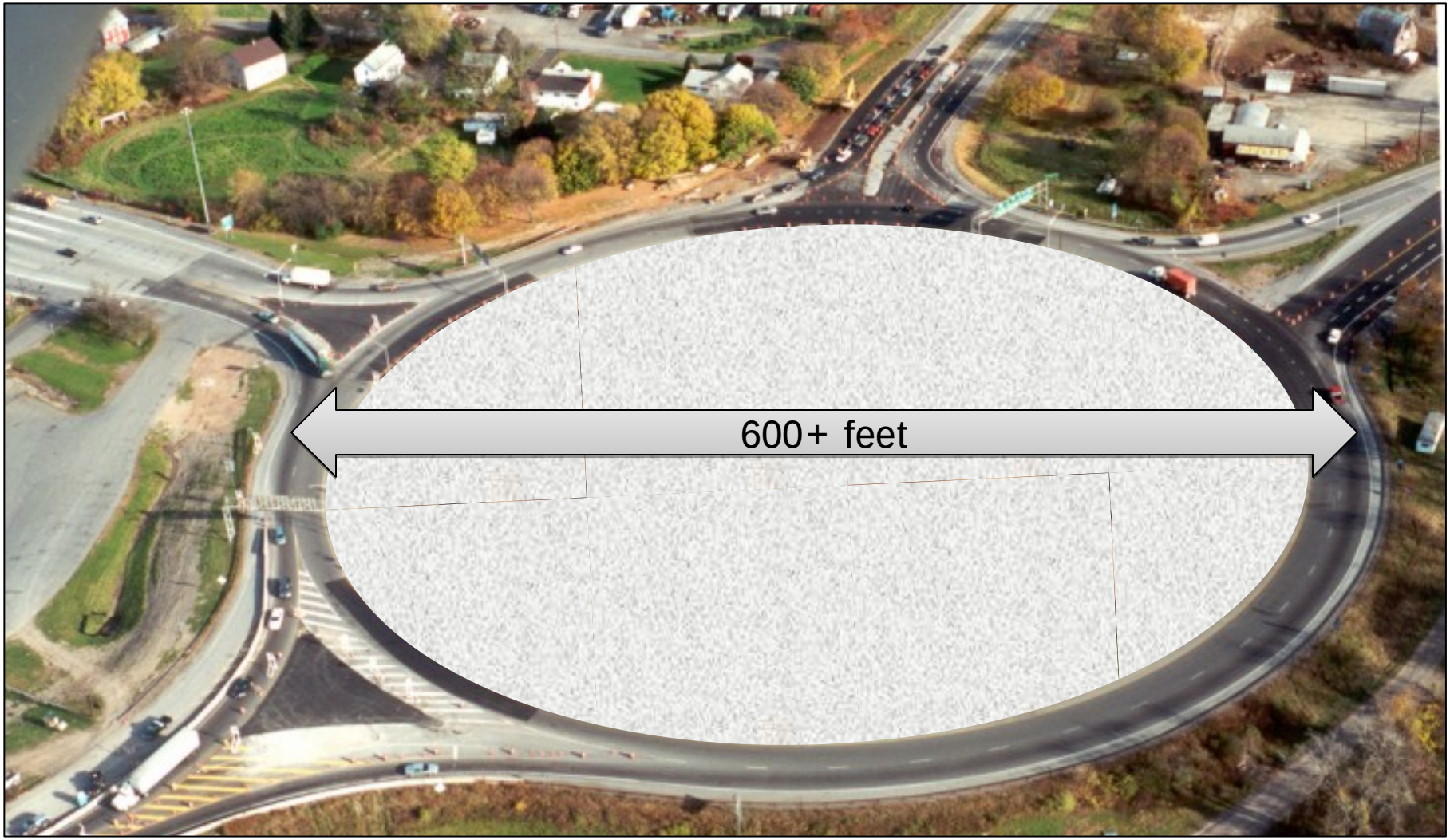
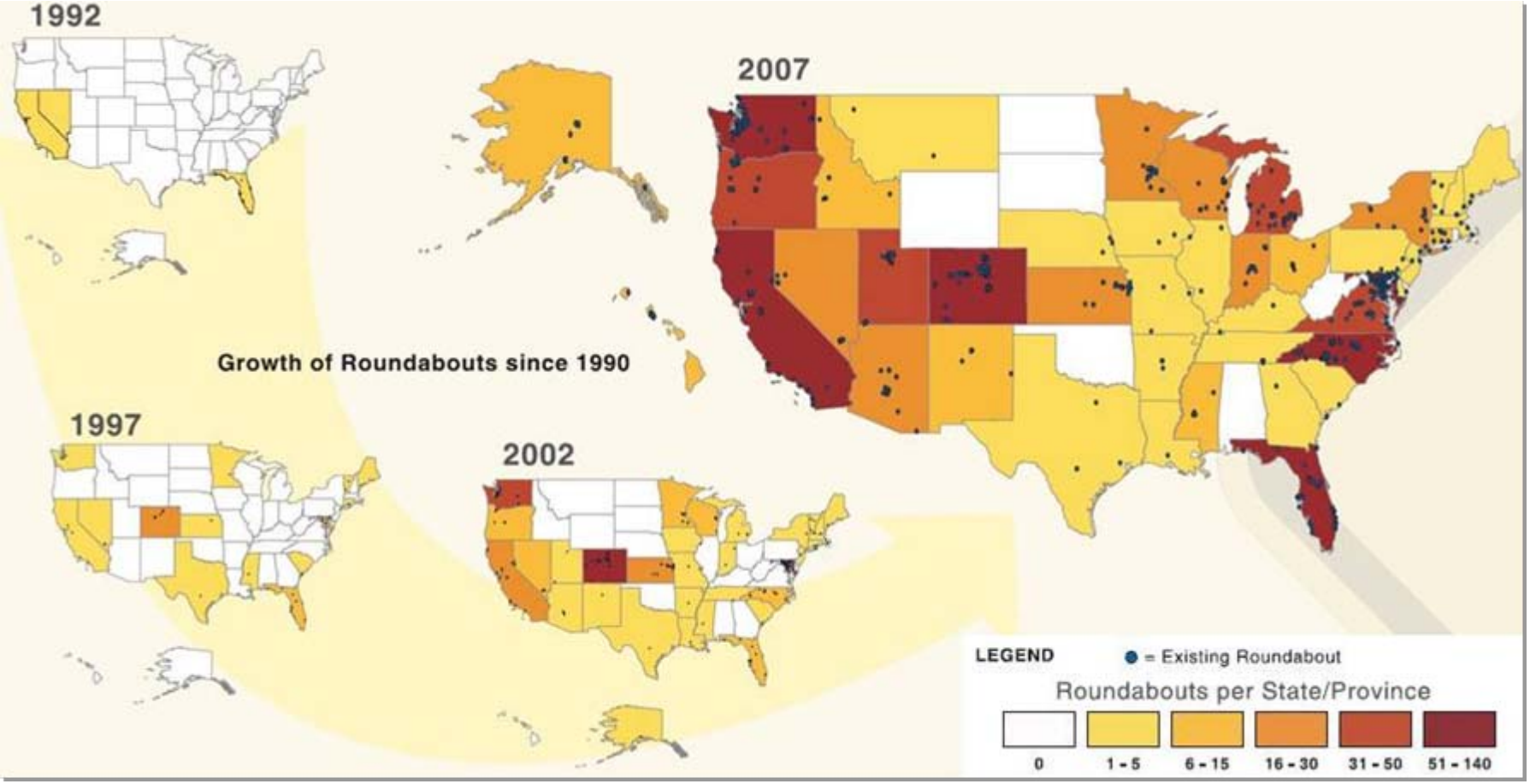
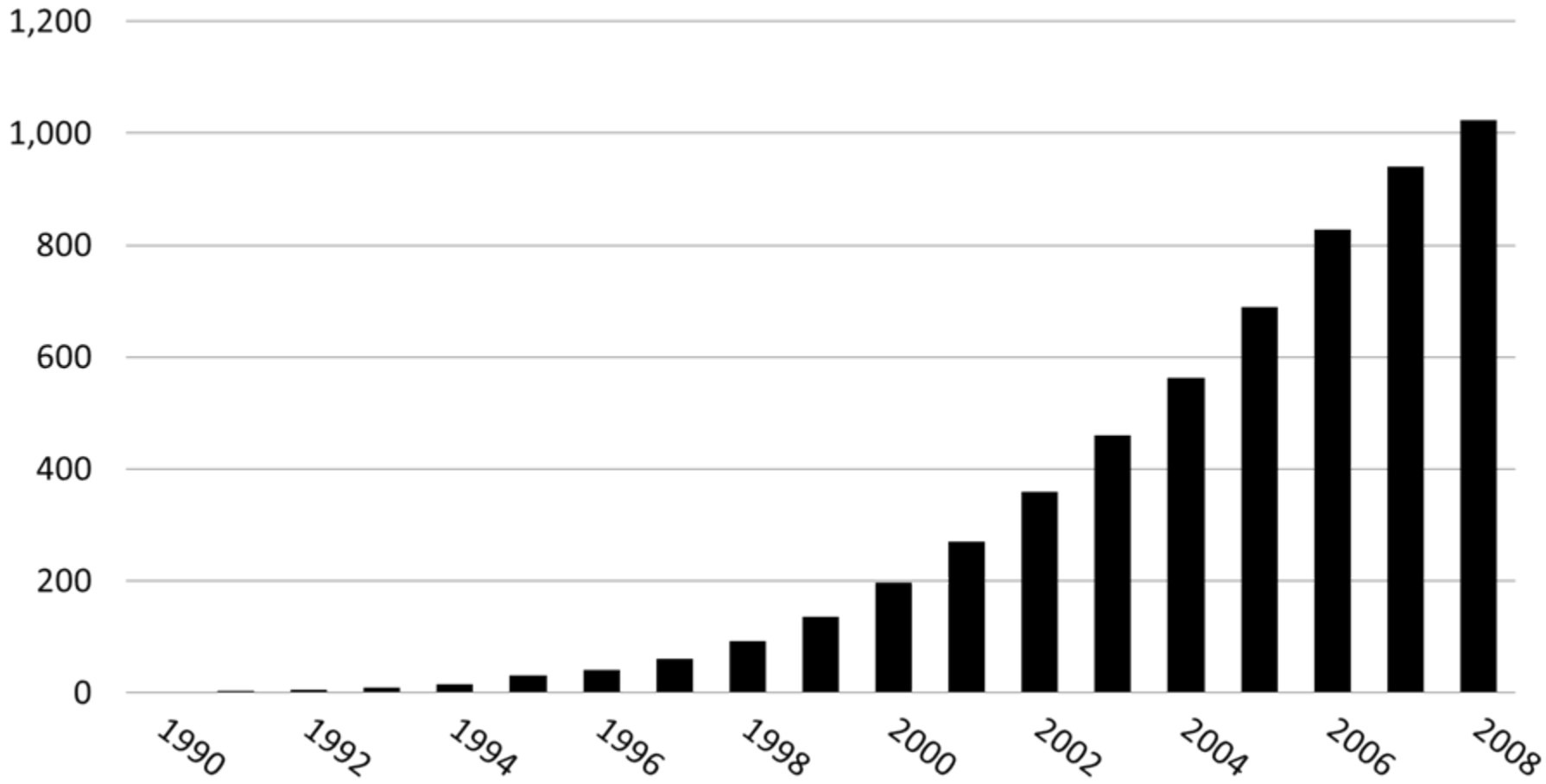


Photo: New York State DOT

Growth in roundabouts in the U.S.



Exponential growth in U.S. roundabouts



Roundabouts are being utilized under a wide variety of conditions

- Freeway interchanges
- High speed rural
- High volume conditions
- High pedestrians
- High truck volumes
- Awkward geometry
- Near schools
- “Gateways” into lower speed facility
- Light rail corridors
- Tourist routes
- Snowy locations

Roundabouts in Oregon

Bend	27	(2)
Sunriver	1	
Springfield	5	(1)
Sherwood	3	
Clackamas Co.	3	(1)
Lake Oswego	2	
Madras	2	
Eugene	2	

Portland	2	
Washington Co.	2	
Beaverton	1	
Albany	1	
Astoria	1	(1)
Medford	1	
Tigard	1	
Newberg	1	

Total: 55 (5) +

( ) = # of multi-lane roundabouts

Urban Single-Lane Roundabout Examples

Terwilliger/Palater
Portland

Century/Colorado
Bend

Urban Multilane Roundabout Examples

Hayden Br. Way/ Pioneer Parkway

Springfield

Stafford/Borland

Clackamas

Key Roundabout Advantages – Better use of Intersection Space and Time

- **Safety**
- **Delay**
- **Emissions**
- **Fuel Savings**
- **Aesthetics**

Rationale for Considering Roundabouts

- **Safety**
  - Reduce number of crashes
  - Reduce severity of crashes
- **Operations**
  - Reduce congestion
  - Reduce emissions

Safety Performance (NCHRP Report 572)

- **Over 90% reduction in fatalities**
  - Some states 100% reduction so far
- **76% reduction in injuries**
- **35% reduction in total crashes**
- **Very little reported pedestrian and bicycle crash experience**

Photo: Lee Rodegerdts

Maryland's Roundabout Safety Experience (March 2007 Study)

- **Overall Crash Reductions:**
  - 68% reduction in total crashes
  - 100% reduction in fatal accident rate
  - 86% reduction in injury accident rate
  - 41% reduction in property damage only accidents

- **Benefit/cost analysis indicated return of $15 for every dollar spent in crash reduction alone.**

Signalized Intersection Crashes in Oregon 2003 - 2007 (5 yrs)

- **At 1,240 <u>Signalized Intersections</u> on State Highways**
  - **32 Fatal crashes**
  - **308 Serious Injury crashes**
  - 5171 Moderate & minor injury crashes

- **As speeds increase, % of crashes resulting in Fatalities & Serious Injuries increases**

  (2.2% @ 20mph, 4.0% @ 45 & 50 mph)

Unsignalized Intersection Crashes in Oregon 2003 - 2007 (5 yrs)

- **11,004 <u>Unsignalized</u> Intersections on State Highways**
  - **105 Fatal crashes**
  - **472 Serious Injury crashes**
  - 4347 Moderate & minor injury crashes

- **As speeds increase, % of crashes resulting in Fatalities & Serious Injuries increases**

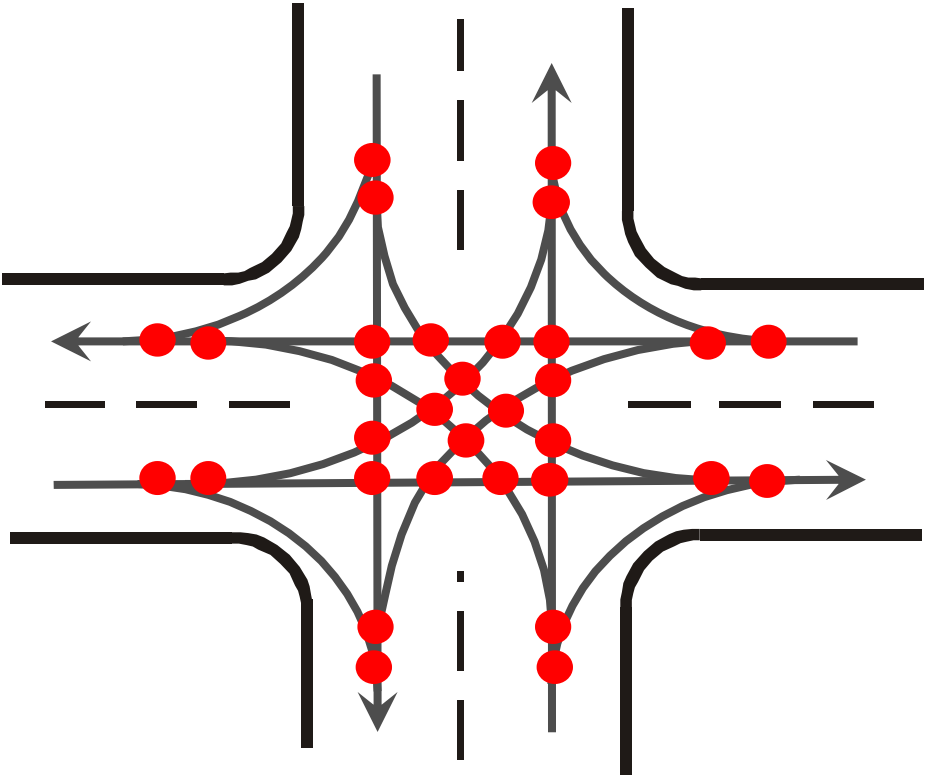
  (2.0% @ 25mph, 10.8% @ 50 mph)

Rationale: Safety

- **Roundabouts have a proven safety record for reducing motor vehicle crashes, particularly injury and fatal crashes**

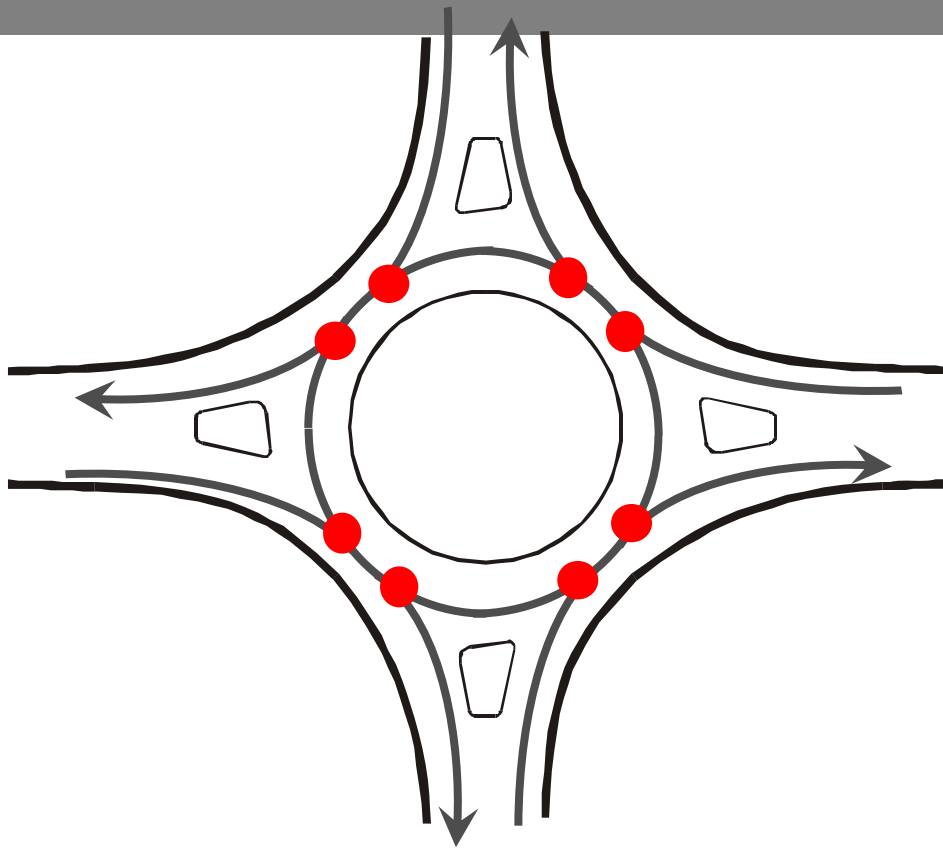
- **Experience is due to basic contributing factors:**
  - Reduced conflict points
  - Reduced conflict severity (crash types)
  - Reduced vehicle speeds
  - Reduced driver decisions

Vehicle Conflict Points: REDUCED



32 conflict points

- High-speed
- Angle Crashes
- **High Impact**



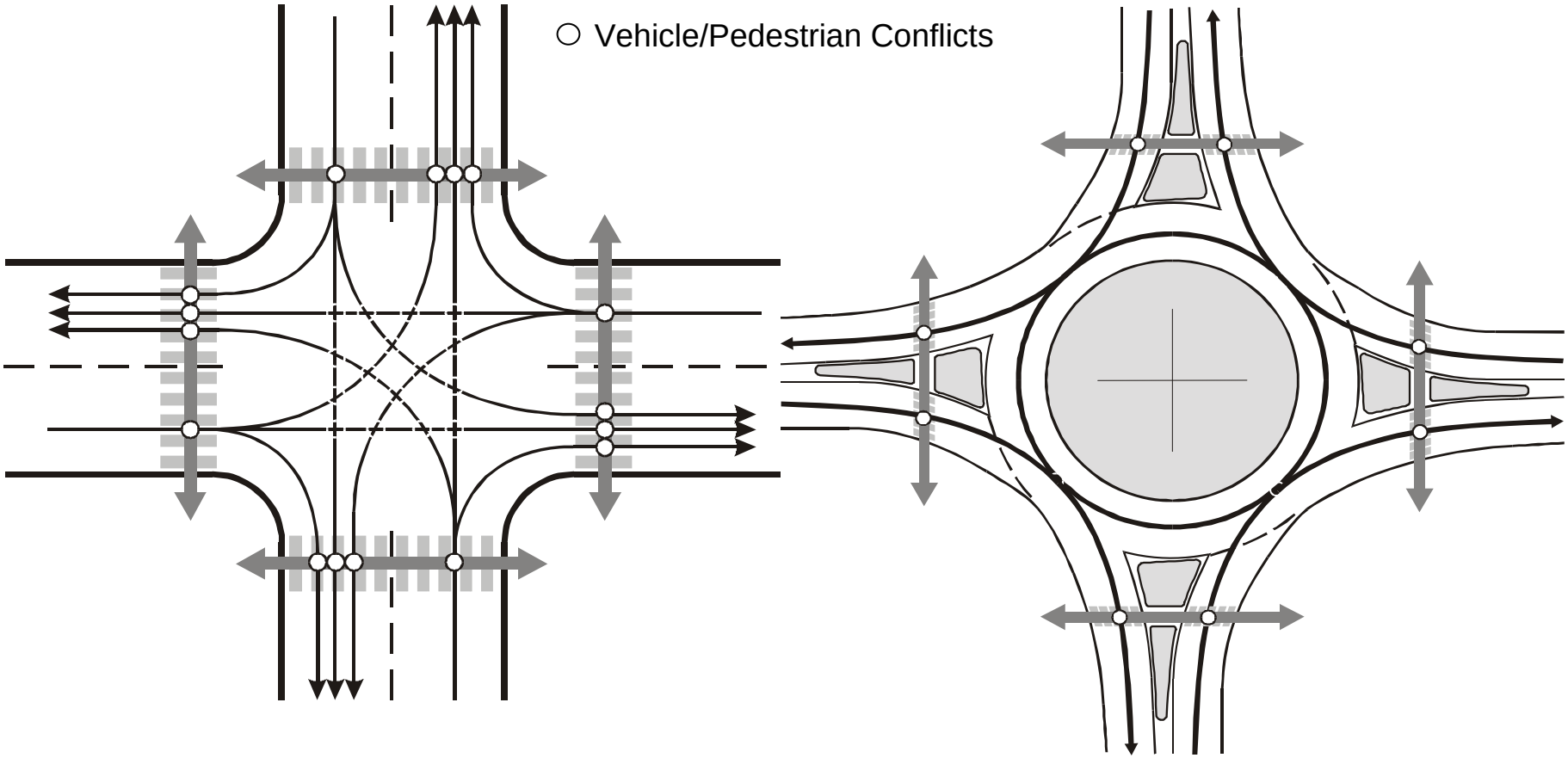
8 conflict points

- Low-speed
- Non-angle Crashes
- **Low Impact**

Vehicle Conflict Points: REDUCED

- 75% fewer conflicts
- Crossing conflicts eliminated at roundabout

Pedestrian Conflict Points: REDUCED

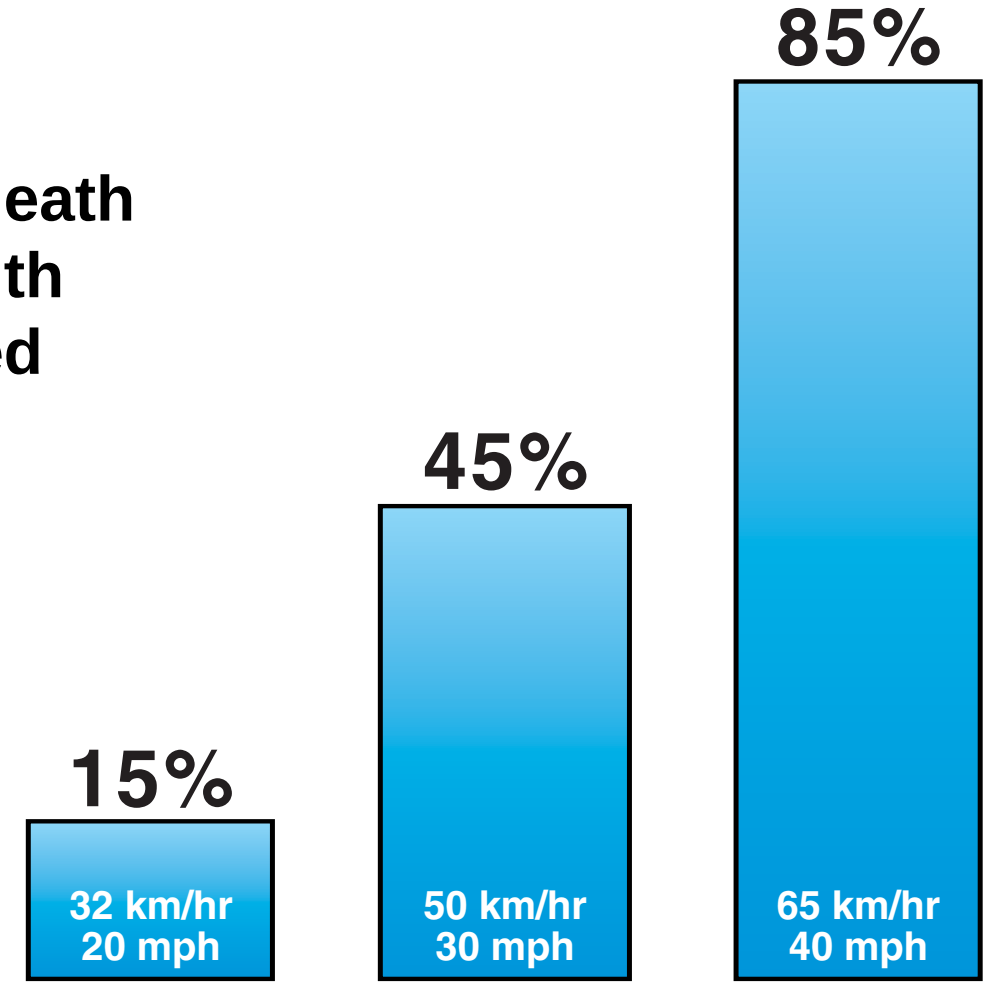


Pedestrian Conflict Points: REDUCED

- Pedestrian conflict points reduced 50%
- Conflicts with pedestrians physically separated from conflicts with vehicles

Lower speed is safer for pedestrians

Chance of pedestrian death increases with vehicle speed

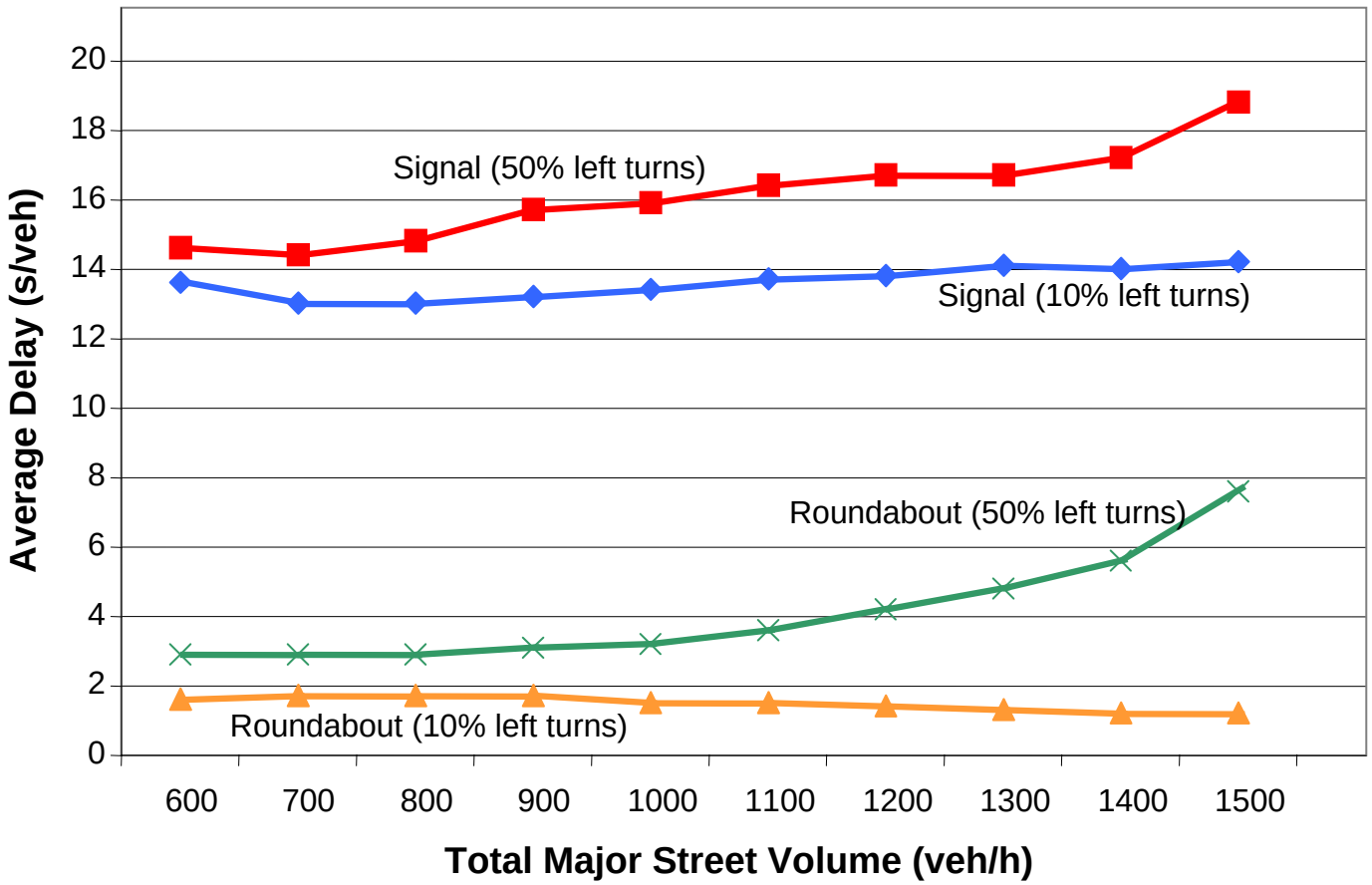


Roundabouts Reduce Delay

- **At 3 sites in NH, NY, & WA where signals or stop signs were replaced w/ roundabouts, delay was reduced by 89% and vehicle stops by 56%.**

- **At 11 intersections in Kansas reductions of 65% and 52% in delay and vehicle stops.**

Roundabouts versus Signals: MUTCD Signal Warrant Threshold



Lower Delay = Lower Emissions

Roundabouts Save Fuel & Reduce Emissions

- **At least two studies have noted that roundabouts can reduce fuel consumption by about 30%.**
- **In one study, replacing a signal with a roundabout reduced CO emissions by 29% and Nitrous Oxide emissions by 21%**
- **Another study noted reductions of 34% NO, 32% CO, 37% CO2 & 42% in hydrocarbons by replacing traffic signals and stop signs**

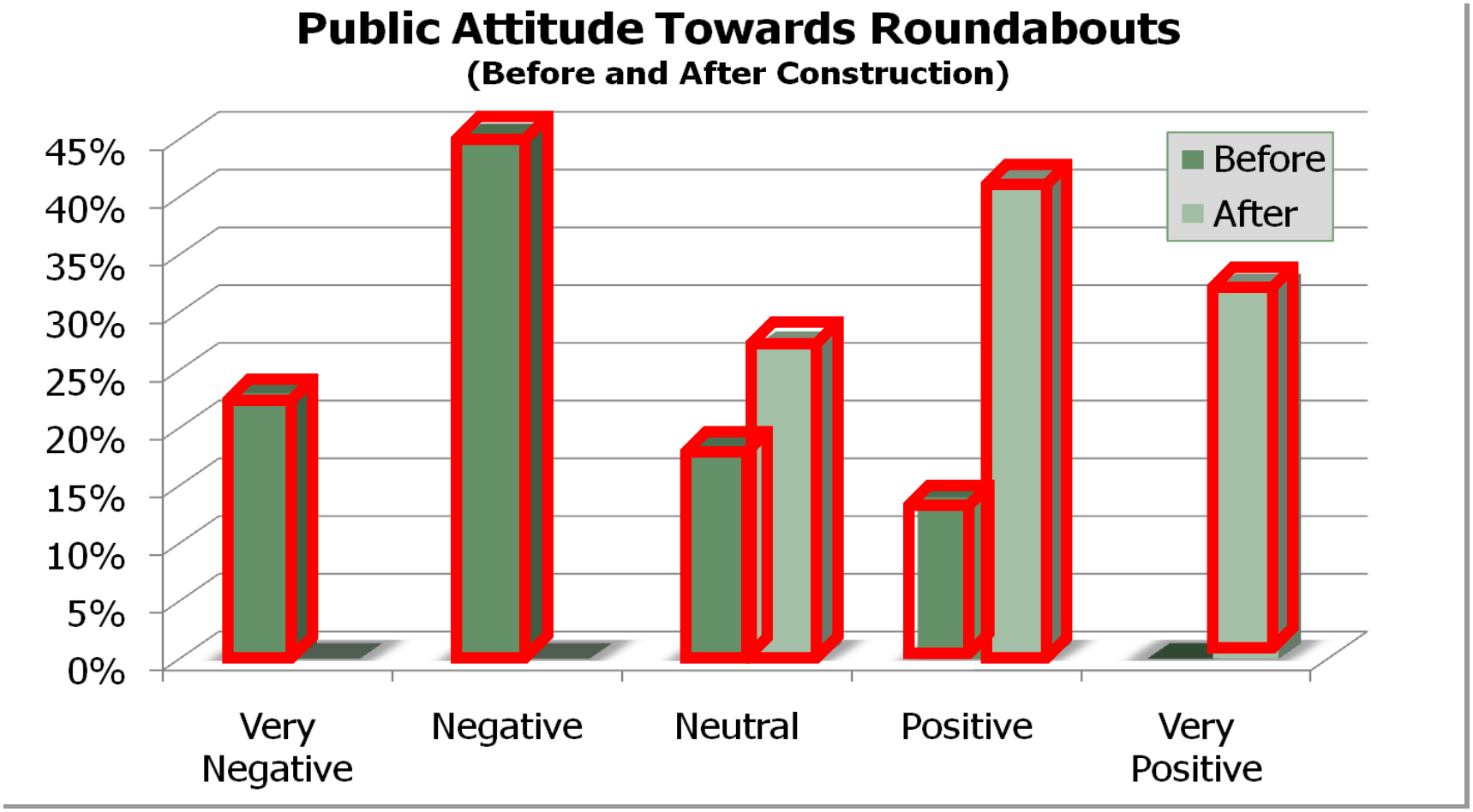
Key Roundabout Advantages – Better use of Intersection Space and Time

- **Safety**
- **Delay**
- **Emissions**
- **Fuel Savings**
- **Aesthetics**

Roundabout Issues

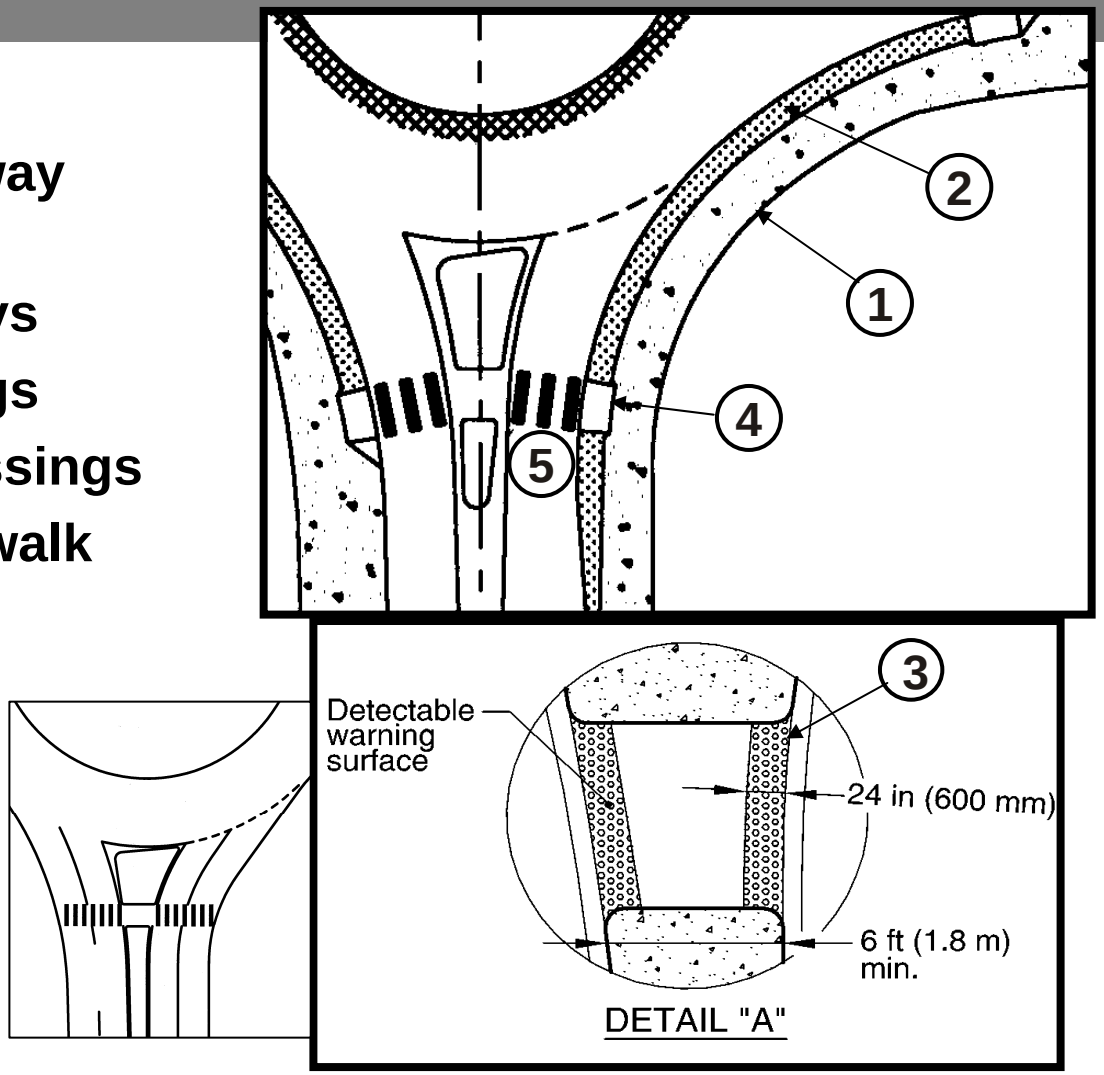
- **Public Acceptance**
- **User Consideration**
  - Pedestrian & ADA questions (at multilane roundabouts)
  - Bicycles
  - **Design Vehicles**

Public perception of roundabouts



Pedestrian Design Guidance

1. **Well defined walkway edges**
2. **Separated walkways**
3. **Detectable warnings**
4. **Perpendicular crossings**
5. **Contrasting crosswalk markings**



Bicycles

- **Roundabouts slow vehicles to speeds compatible with bicycles**
- **Bicycle speeds: 10-15 mph**
- **Bicyclists have wide range of skills and comfort levels in mixed traffic**
  - Experienced cyclists (e.g., commuter or utility cyclists)
  - Inexperienced cyclists (e.g., children or occasional recreation cyclists)
- **Give bicyclists option of either being vehicle or pedestrian**

Design vehicle - Can design for any vehicle

Truckee, California

Portland, Oregon

Photos: Lee Rodegerdts

Concerns/Issues Raised

- Can trucks fit through single-lane roundabouts?
- What about the overtracking issue at multilane roundabouts?
- Don’t roundabouts slow down the movement of freight?
- How are you going to accommodate oversize loads?

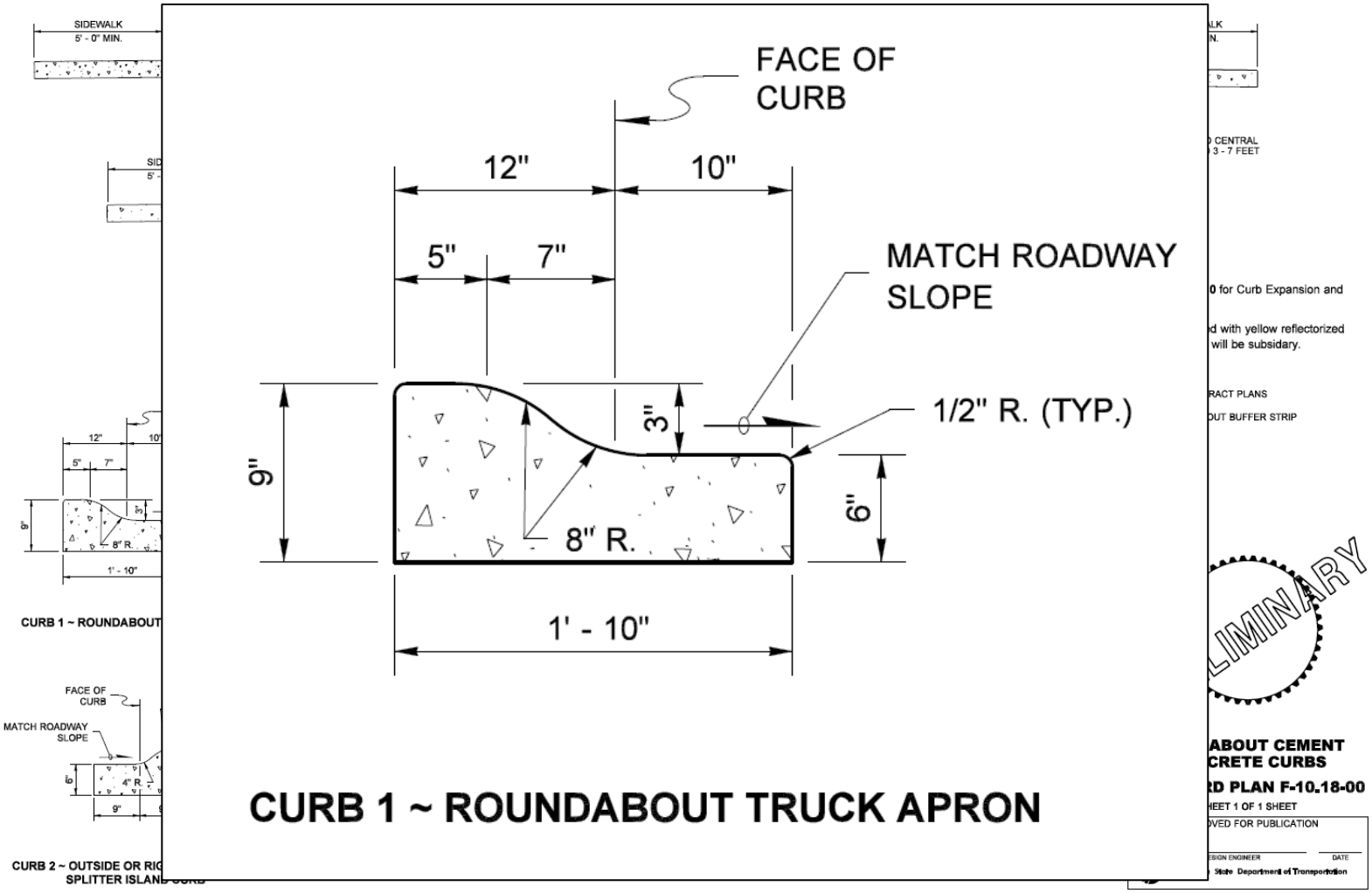
Can trucks fit through single-lane roundabouts?

Photo: Lee Rodegerdts

Design for Appropriate Design Vehicle:

- Truck Aprons
- Appropriate width entries and exits
- Placement of signs

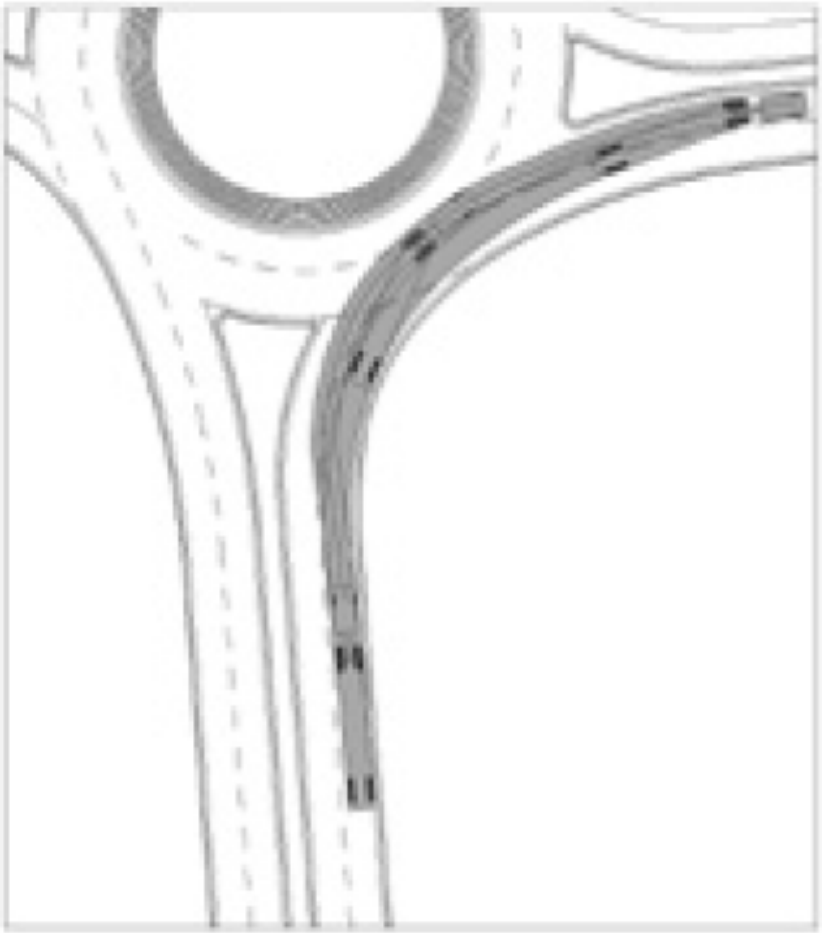
Design details – WSDOT ‘friendly’ curbs

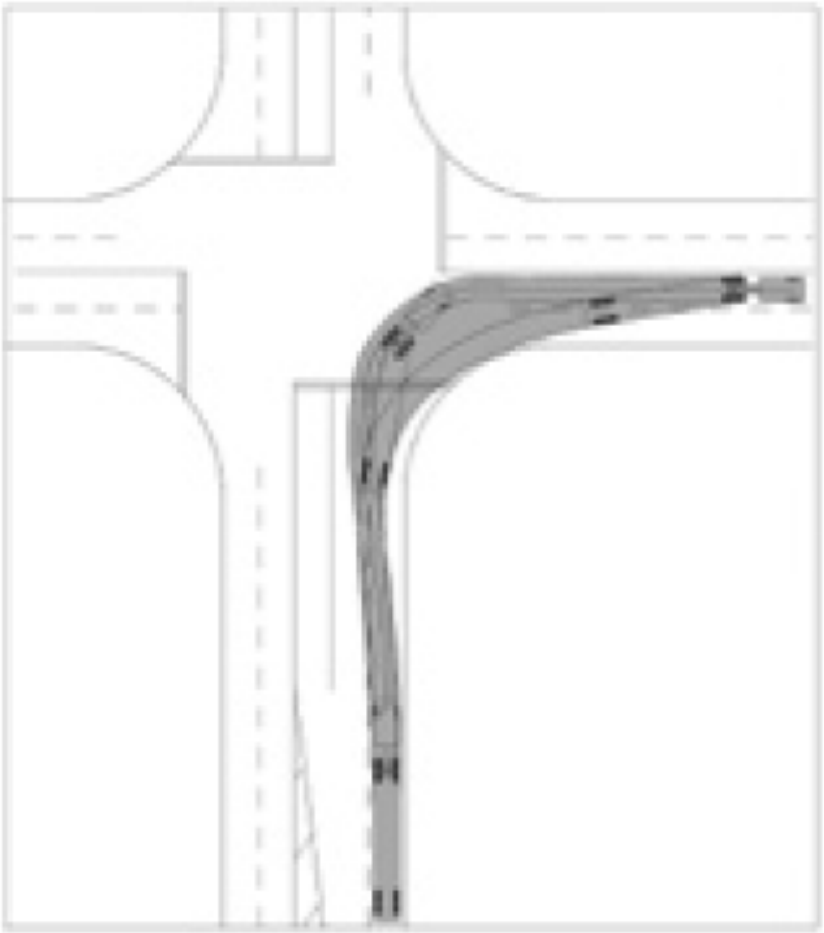


What about the overtracking issue at multilane roundabouts?

- Concern with liability when passenger cars attempt to pass or circulate next to trucks
- Many roundabout designs permit the average truck to maintain their lane and not overtrack

Lane Overtracking – Not Unique to Roundabouts





Source: ITE Journal, Wadell et al

Lane overtracking – potential solutions

- Signage
- Legislation – SB 341
  - Modify Oregon Revised Statute (ORS) 811.292 in the Oregon Vehicle Code to prohibit passing, overtaking, or driving alongside a commercial motor vehicle in a multilane roundabout.
  - As amended, it would also allow trucks to use more than one lane as they go through the roundabout.

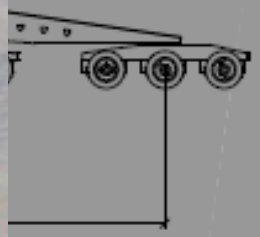
Don’t roundabouts slow down the movement of freight?

- Trucks must slow down to negotiate roundabout
  - Negligible delay in overall travel time for a trip
- Example: Golden, CO
  - Converted a series of four formerly signalized intersections to roundabouts
  - Speeds between the intersections fell to an average of 37 mph from 47 mph
  - But the time to travel the entire corridor ***dropped***.

How are you going to accommodate oversize loads?

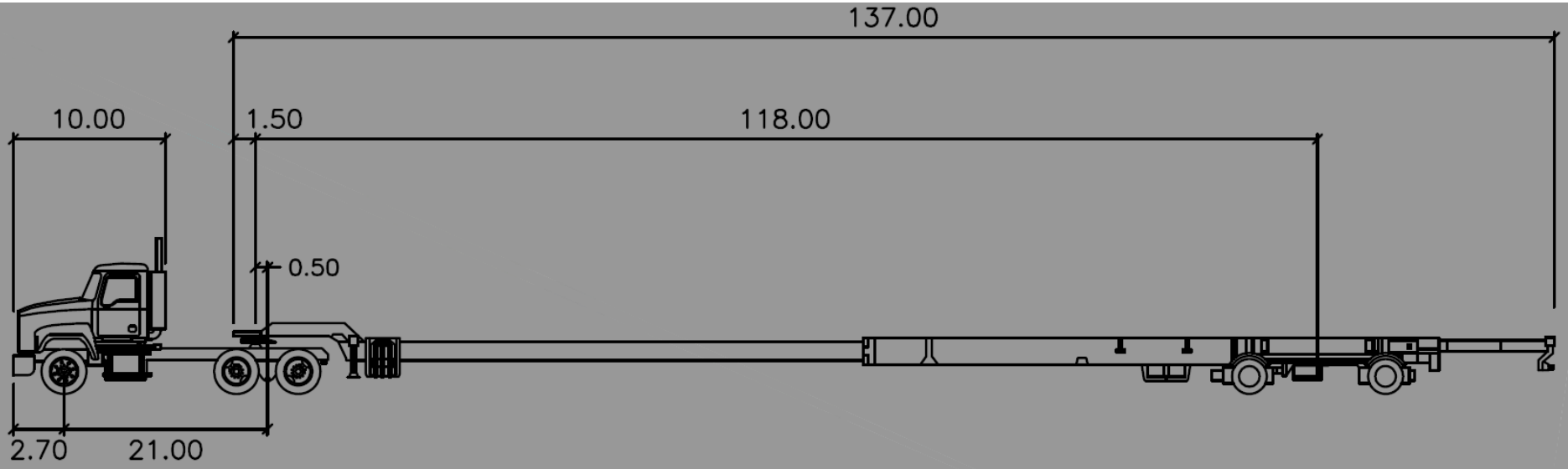
- Evidence that many oversized loads can fit through roundabouts
- Restrictions at intersections not unique to roundabouts
- Design alternatives to accommodate the exceptions

19-Axle Heavy Haul



19-Axle Heavy Haul

Wind Blade



Wind Blade Trailer feet

Tractor Width	: 8.00	Lock to Lock Time	: 6.0
Trailer Width	: 3.00	Steering Angle	: 40.0
Tractor Track	: 8.00	Articulating Angle	: 70.0
Trailor Track	: 8.00		

Wind blade

Maryland roundabout

Source: Maryland State Highway Administration

Design alternatives to accommodate the exceptions

Design alternatives to accommodate the exceptions

Benefits to the freight industry

- Cost of crashes involving trucks (2007 FMCSA)
  - Fatality = $3.6 million per crash
  - Injury = $200,000 per crash
  - All crashes = $91,000 per crash
- Roundabouts result in:
  - 80-90% reduction in injury crashes
  - 90-100% reduction in fatal crashes
- Savings to freight industry
  - Lower insurance costs
  - Less driver and truck downtime due to crashes
  - Less incident-related delay to freight movement

Truck drivers not at fault in majority of crashes…

- AAA Foundation for Traffic Safety Study (2000)
  - 5,211 people were killed and about 140,000 injured in crashes involving large trucks
  - 98% of fatalities occurred in the car
  - **Car drivers were to blame in 75% of the crashes**

…but still deal with consequences.

Intersection has long been a deadly site

Two teens die in U.S.-50/77 collision

Two teenage girls are dead after a semi collided with their car Thursday at a dangerous Marion County intersection.

Alison Cady, 16, and Lyndsay Sherbert, 15, were killed instantly when a tractor-trailer collided into the passenger side of their car. They were cross- tersection north of dent took place just

rion County Under- azil, Sherbert was d Taurus, with Cady Sherbert stopped at roceeded across the

ck by a 1995 Volvo lling West Trucking a, with Alvin Wad- driving the truck. He

me to rest in a ditch intersection. EMS, sponded from Flo- The Marion Coun- ment and Marion County emergency also came to the scene.

Cady was the daughter of Jeff and Theresa Cady of Marion. Funeral services were held Monday morning at Holy Family Parish, St. John Nepomucene Church, Pilsen.

Sherbert was the daughter of Daniel Sherbert of Marion and Luanne Molzen of Kinsley. Funeral services were held Tuesday morning at Our Savior Lutheran Church of Marion, and a memorial service took place Wednesday morning in Kinsley.

Alison Cady

Lyndsay Sherbert

Source: Kansas DOT and Marion County Record

Benefits to the freight industry

- Cost of highway diesel fuel increased 126 percent over the decade ending in 2006
  - *Opportunity for 30% reduction at intersections with roundabouts*

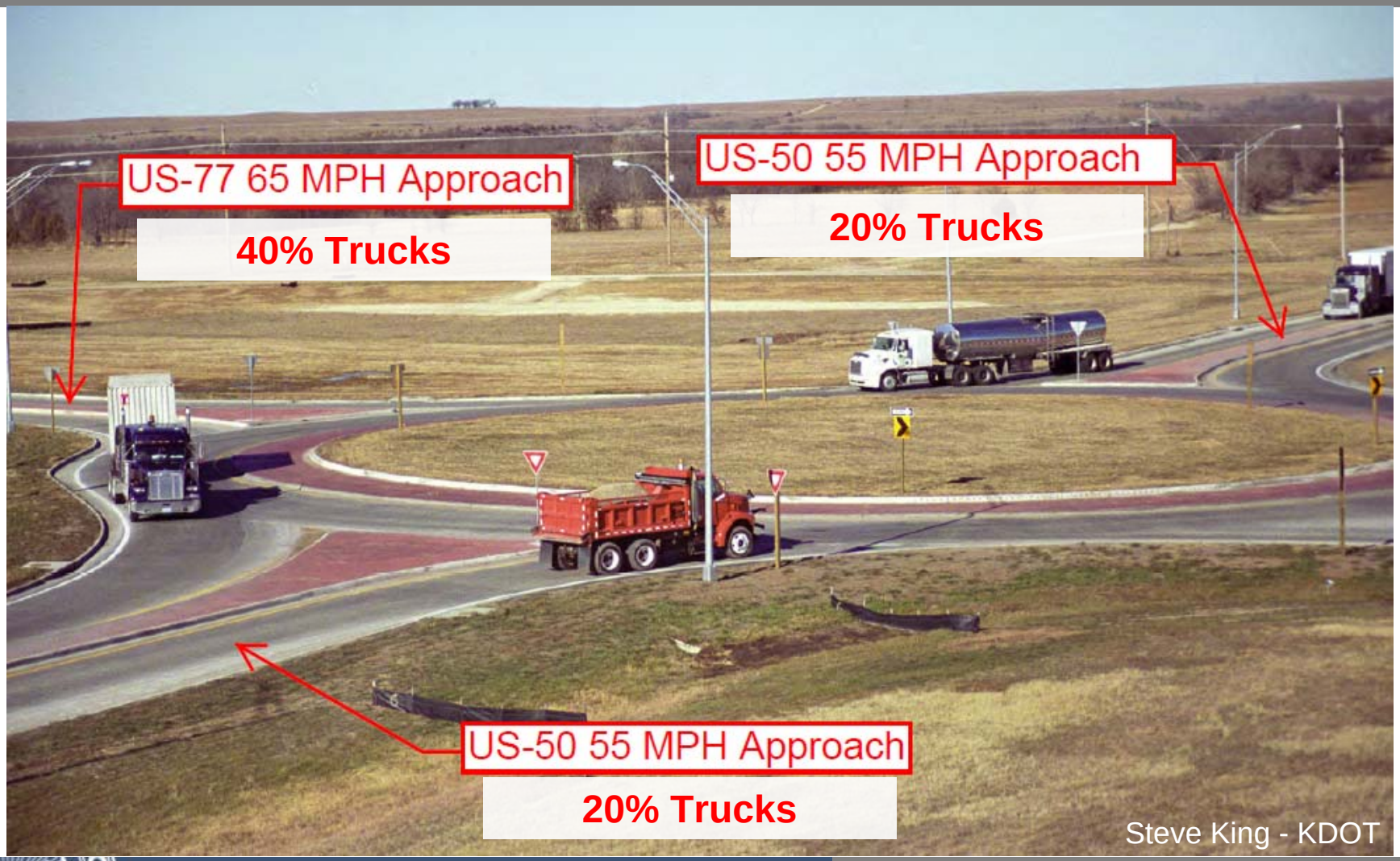
- 2008 FHWA Bottleneck Study
  - Sample of 559 bottlenecks caused by signalized intersections
  - Total delay estimate associated nationally with this type of bottleneck in 2006 was about **48 million truck hours of delay**
  - At a delay cost of $32.15 per hour, the direct user cost of the bottlenecks is about **$1.5 billion per year**
  - *Opportunity for 65-89% reduction at intersections with roundabouts*

Benefits to the freight industry

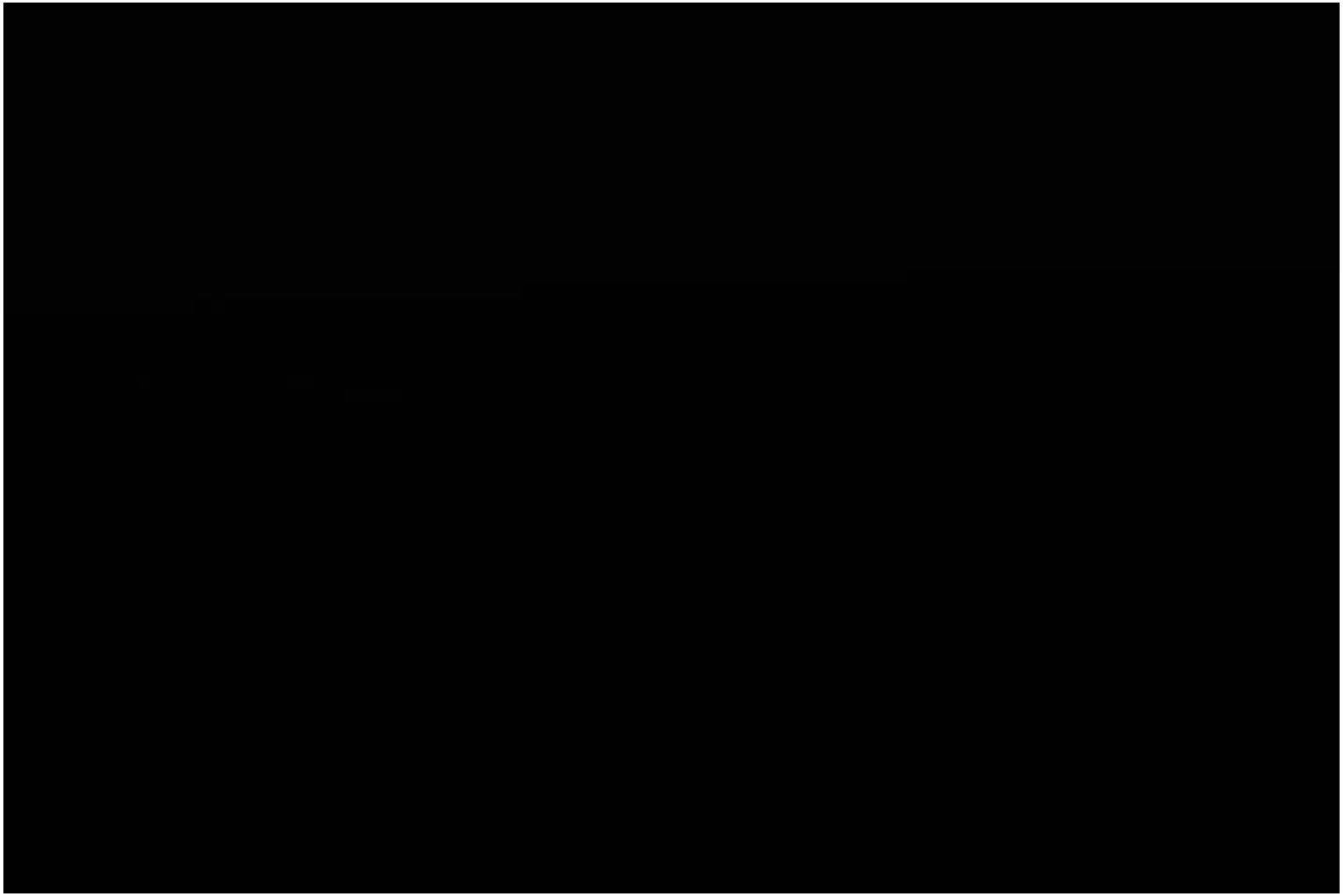
- No overhead restrictions
  - *No need to remove signal heads and mast arms*

US 50/US 77 – Florence, KS

US 50/US 77 – Florence, KS



US 50/US 77 – Florence, KS

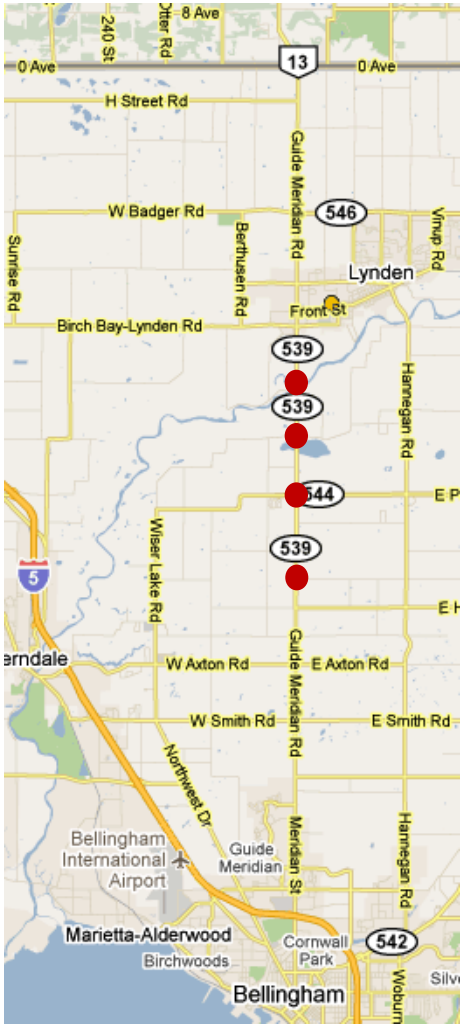


US 50/US 77 – Florence, KS

US 50/US 77 – Florence, KS

Guide Meridian (SR 539) – Whatcom County, WA

- 16,000 ADT with 15% trucks
- Alternate border crossing route
- Reduce congestion, improve safety and enhance freight mobility
- Roundabouts at Ten Mile Road, Wiser Lake Road, River Road, and Pole Road (SR 544)



Education and outreach: Roundabout Rodeo

"As long as they educate the guys driving the pickups and cars, we'll be okay."

Len Honcoop, owner of Honcoop Gravel

SR 539/Pole Road Roundabout

SR 539/Pole Road Roundabout

Example of oversized vehicles

Final Message

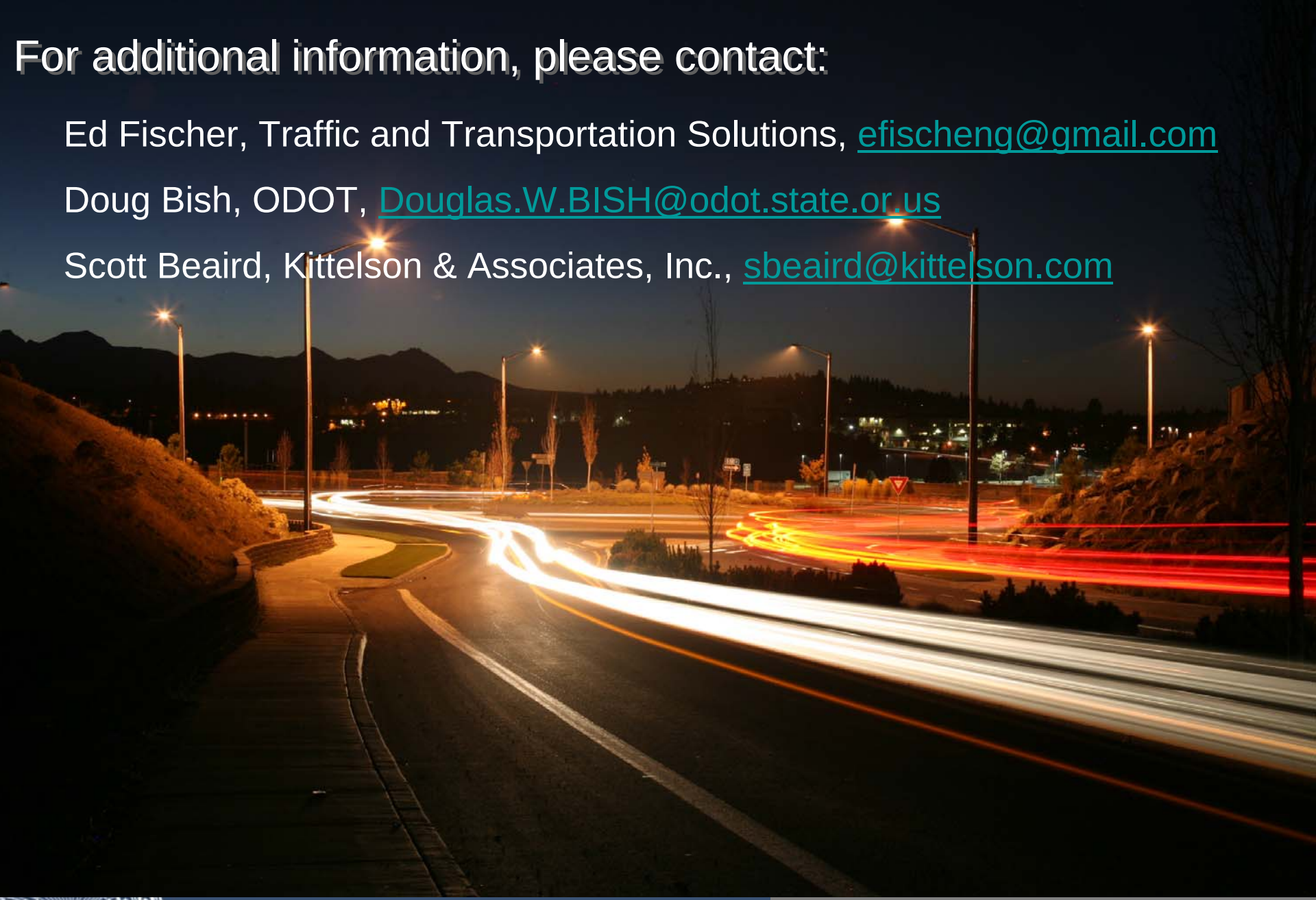
- Roundabouts are an effective tool in reducing delay and improving safety
- Roundabout design practices have evolved
- Roundabouts, considered on a case-by-case basis, can be successfully designed and constructed to accommodate freight
- Continued education of public
  - Roundabouts are just another type of intersection
- Continued education of professionals
  - Continued development of standards/policy/guidance

For additional information, please contact:

Ed Fischer, Traffic and Transportation Solutions, efischeng@gmail.com

Doug Bish, ODOT, Douglas.W.BISH@odot.state.or.us

Scott Beaird, Kittelson & Associates, Inc., sbeaird@kittelson.com



Case Study: Yturri Beltline/Washington Avenue

Case Study: Yturri Beltline/Washington Avenue

Ytuurri Beltline/Washington Avenue Peak Season Peak Hour Operations

Approach	Approach Volume AM (PM)	Critical Movement	AM Peak Hour			PM Peak Hour		
			Delay	V/C	LOS	Delay	V/C	LOS
Westbound	158 (245)	Left	25.4	0.13	D	28.8	0.21	D
Eastbound	*33 (67)*	*Left-Thru-Right*	*41.6*	*0.35*	*E*	*53.0*	*0.57*	*F*
Northbound	184 (266)	Left	8.1	0.01	A	7.7	0.01	A
Southbound	425 (357)	Left	8.4	0.15	A	8.7	0.16	A

Case Study: Yturri Beltline/Washington Avenue

- **Signal not warranted**
- **Likely not warranted for at least 10 years**

Roundabout-Signal Comparison: Yturri Beltline/Washington Avenue

Approach	Approach Volume AM (PM)	Roundabout			Traffic Signal		
		Delay	V/c	LOS	Delay	V/c	LOS
Westbound	158 (245)	6.1	0.43	A	17.0	0.40	B
Eastbound	33 (67)	1.6	0.14	A	15.7	0.18	B
Northbound	184 (266)	5.9	0.45	A	10.2	0.29	B
Southbound	425 (357)	***5.8***	***0.47***	***A***	10.6	0.38	B

Rural Roundabout Module

Rural roundabouts

- **Design objective is to raise awareness**
  - Visibility
    - **Terminal vista**
    - **Illumination**
  - Curbing
  - Splitter islands
  - Approach curves

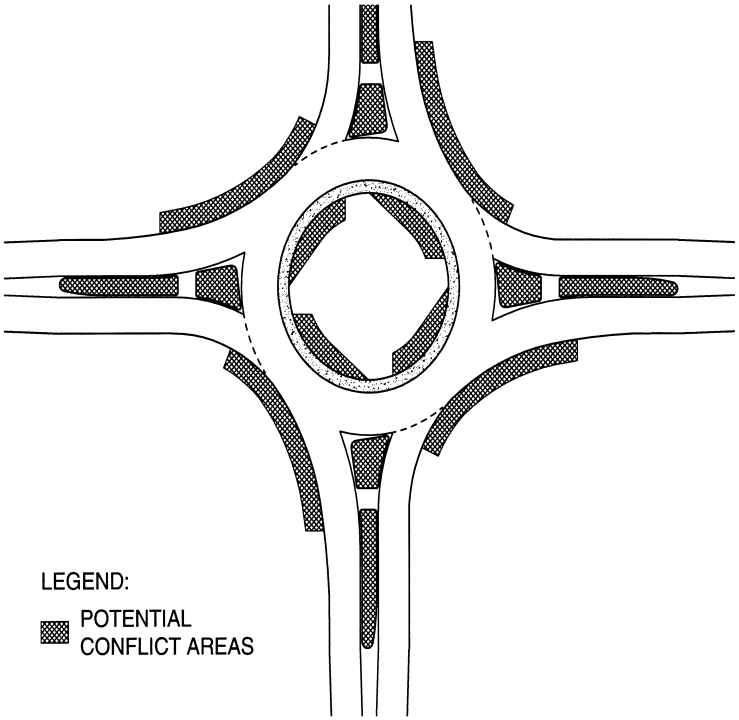
Rural Roundabouts – visibility

- **Terminal vista**
  - Mounded, landscaped central island

Rural Roundabouts – visibility

Rural Roundabouts – visibility

- **Illumination**
  - Some roundabouts are rural today but will be developing into urban/suburban areas
  - Recommend using urban illumination levels based on expected traffic volume and pedestrian activity (design year)



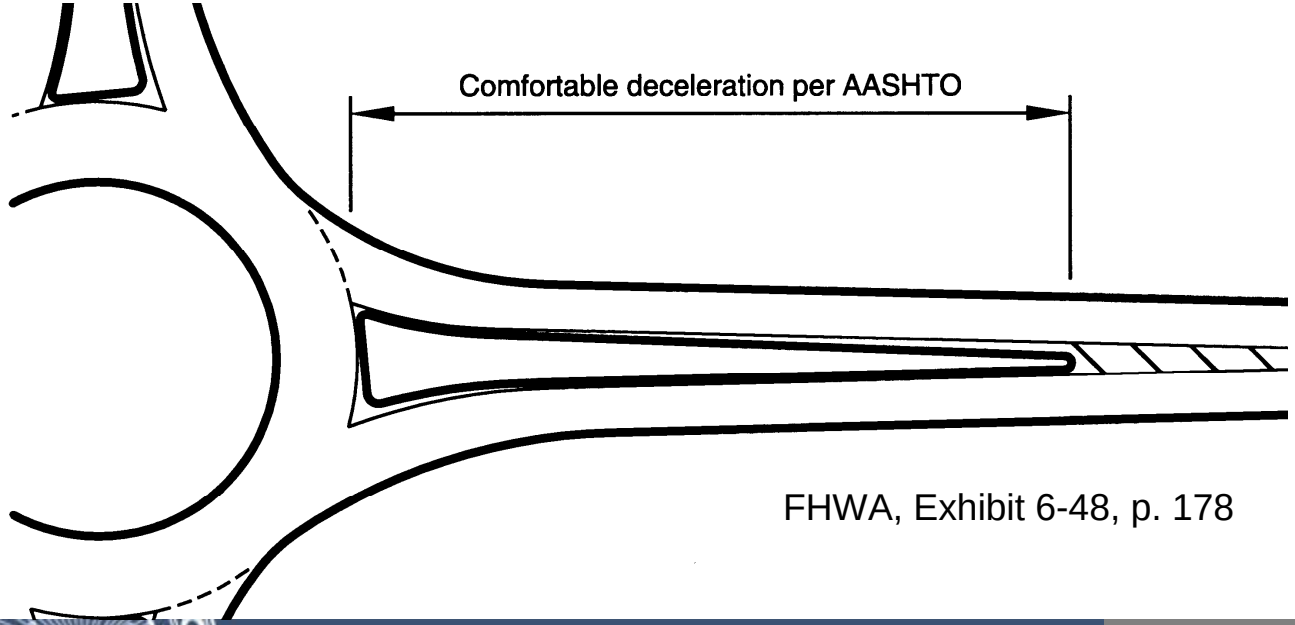
- **Advance warning**
  - If necessary

Rural Roundabouts – curbing

- **Change in cross section alerts driver of upcoming intersection**
- **Creates "funneling" effects, along with extended splitter islands**

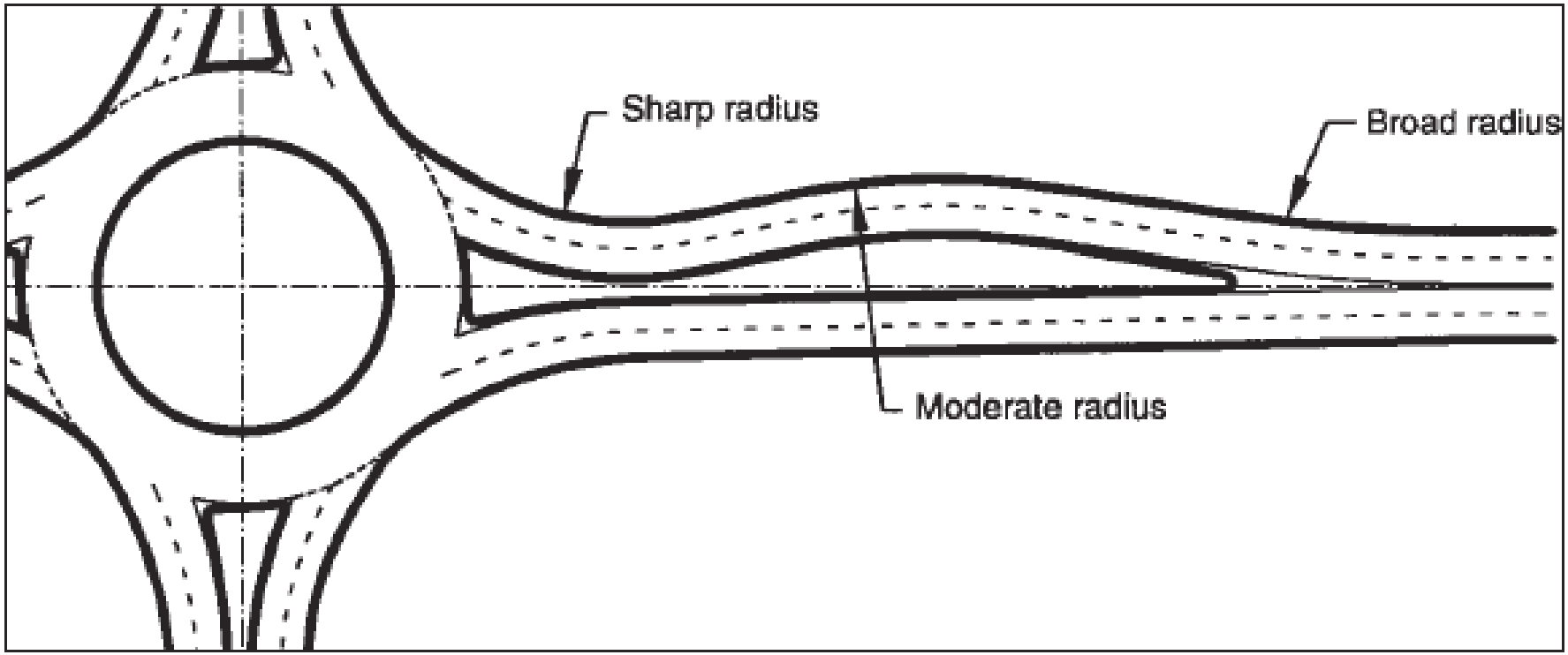
Rural roundabouts – splitter islands

- **AASHTO Exhibit 10-73 – Deceleration lengths**
  - Design speed = 65 mph
  - Target speed = 25 mph
  - Desired deceleration length = 500 - 570’



FHWA, Exhibit 6-48, p. 178

Rural Roundabouts – approach curves



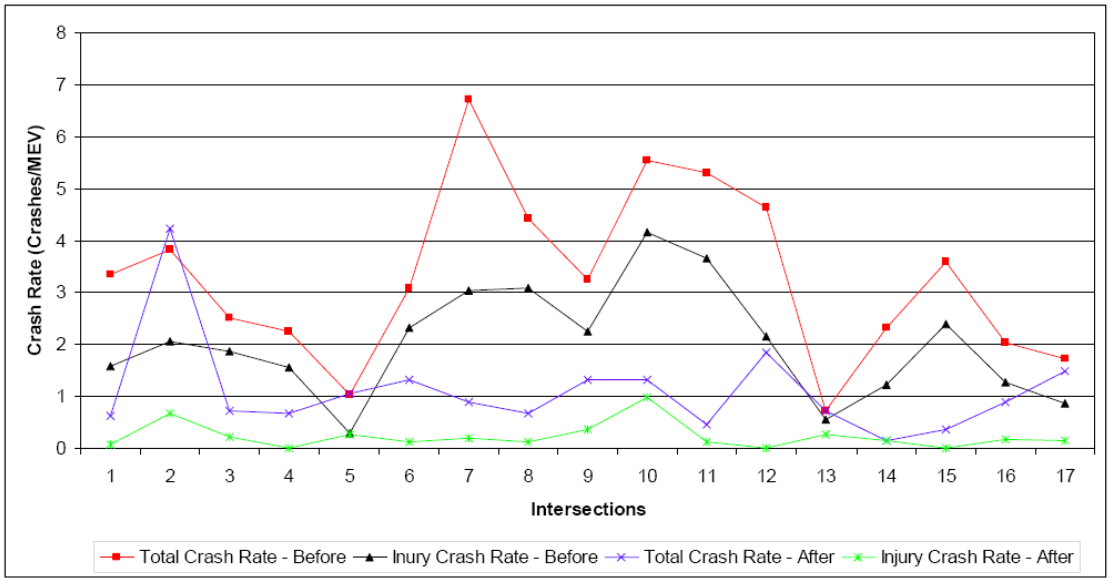
Safety performance of rural roundabouts on high-speed facilities

- **Persaud: Single-lane, rural roundabouts**
  - 58% reduction in total crashes
  - 82% reduction in injury crashes

- **Maryland SHA:**
  - 79% reduction in injury crashes

Safety performance of rural roundabouts on high-speed facilities

- **Isebrands, 2008**
  - Seventeen roundabouts
  - Approach speeds of 40 to 65 mph
  - Crash Rate Reduction
    - **Total – 67%**
    - **Injury – 89%**
    - **Fatal – 100%**



Isebrands, TRB 2008

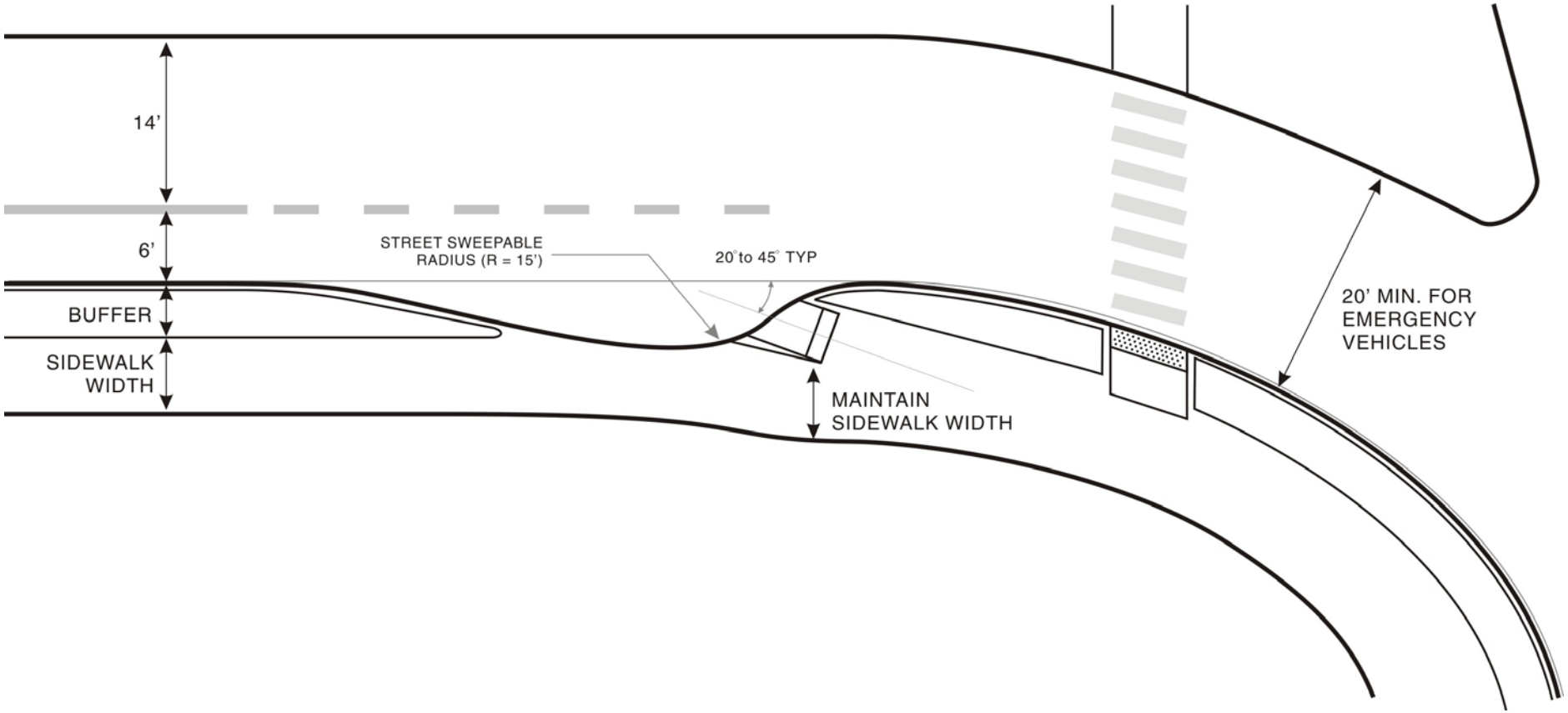
User types at rural roundabouts

- **Pedestrians/Cyclists?**
- **Emergency vehicles**
- **Oversized design vehicle**
- **Snow plows**
- **Farm equipment**
  - Combine
  - Large tractor

Scott County, MN Examples

RESERVE SLIDES

Example Bicycle Treatments



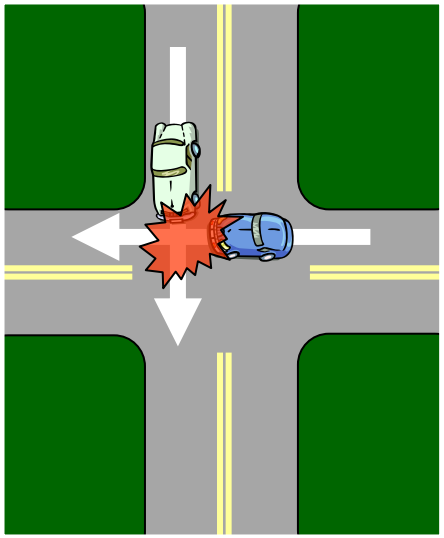
Bicycle Treatments: Grand Junction, CO

Source: City of Grand Junction, CO

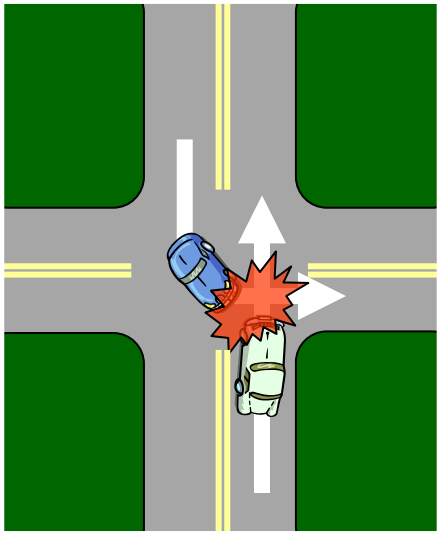
Type of Crashes

Typical 4-leg intersection

Angle

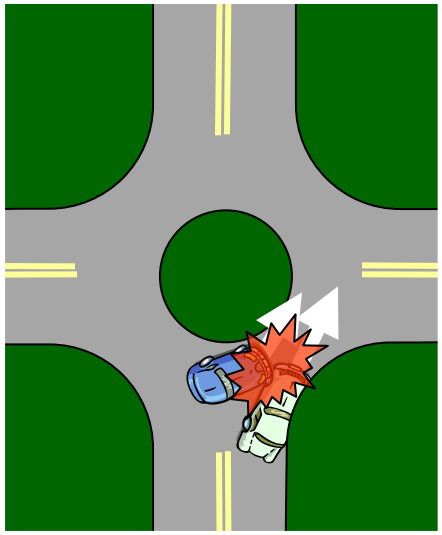


Left turn



Roundabout

Sideswipe



Save Money

- **No signal equipment to install, power, and maintain**
- **May require less right-of-way**
- **Less pavement may be needed**

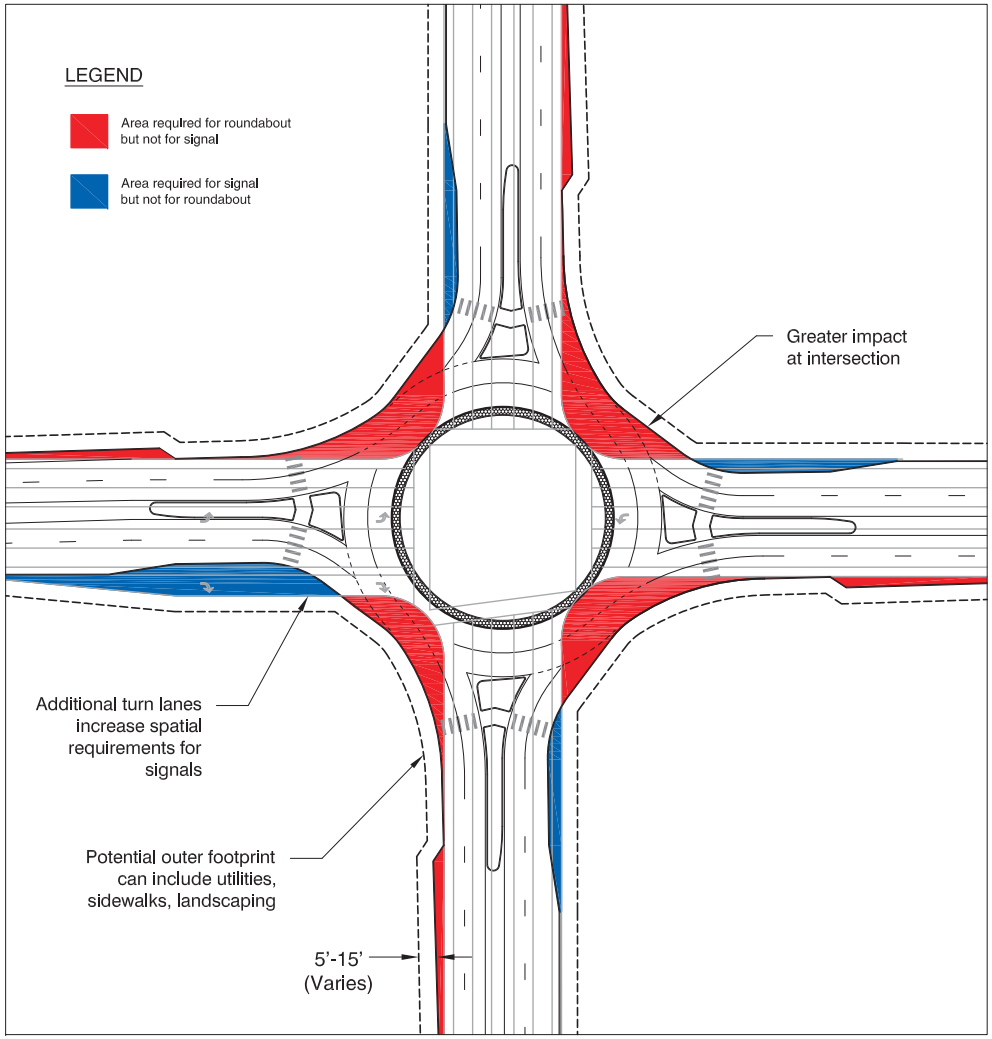
Rationale: Land Use

- **Reasons other than safety or operations**
- **Possible candidates**
  - Community enhancement
  - Gateway treatment
  - Break between conflicting land uses
    - **Urban vs. rural**
    - **Commercial vs. residential**

Example of Land Use: Clearwater, FL

Photo: City of Clearwater, FL

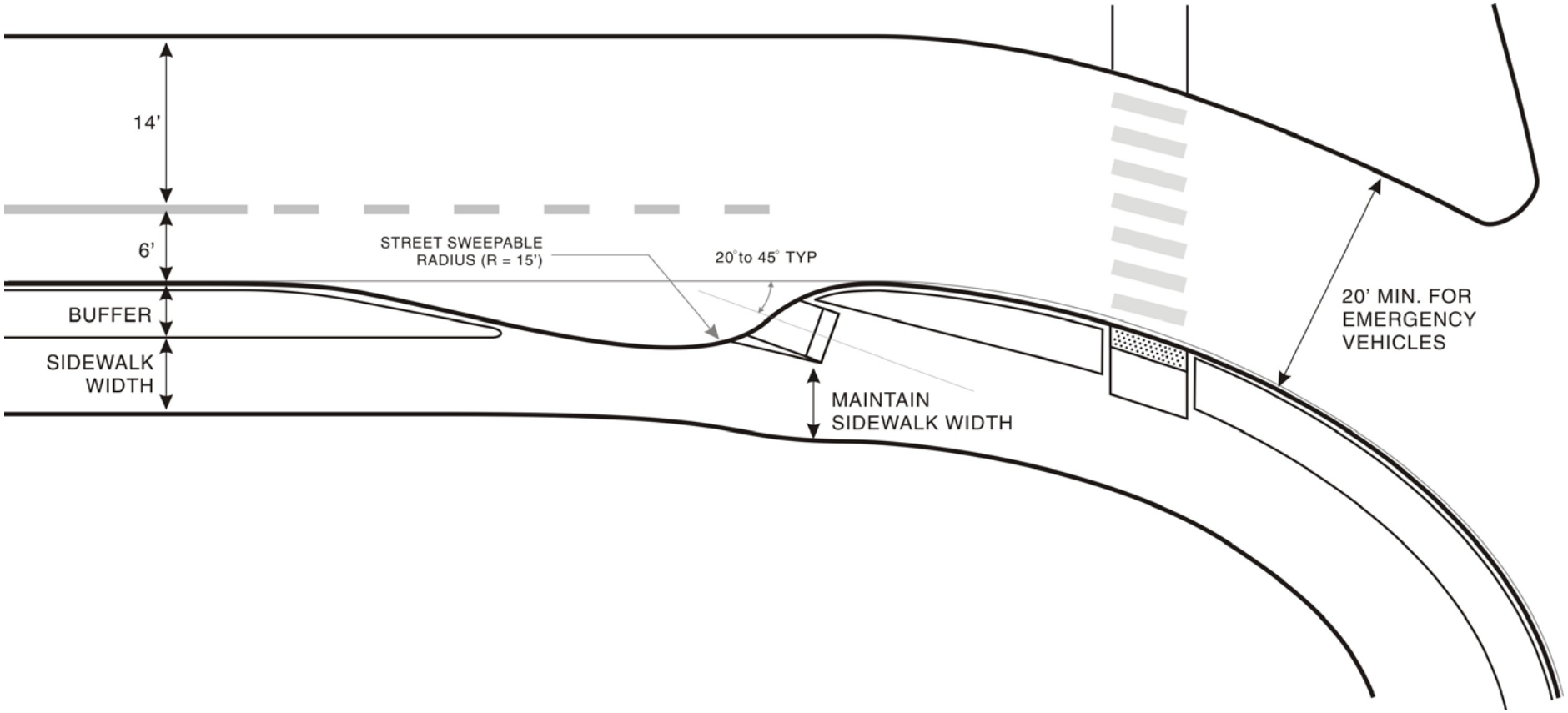
Space considerations



Rationale: Geometry

- **Unusual geometric configurations may lend themselves to a roundabout**
- **Possible candidates**
  - More than four legs
  - “Y” configuration with high-speed movements
  - Need for U-turns
  - Freeway interchange ramps

Example Bicycle Treatments



Bicycle Treatments: Grand Junction, CO

Source: City of Grand Junction, CO

Roundabouts in Corridors

Roundabouts in Interchanges

- **Fewer queue backups**
- **Less bridge width possible**

Roundabouts and Rail Crossings

Roundabouts and Schools

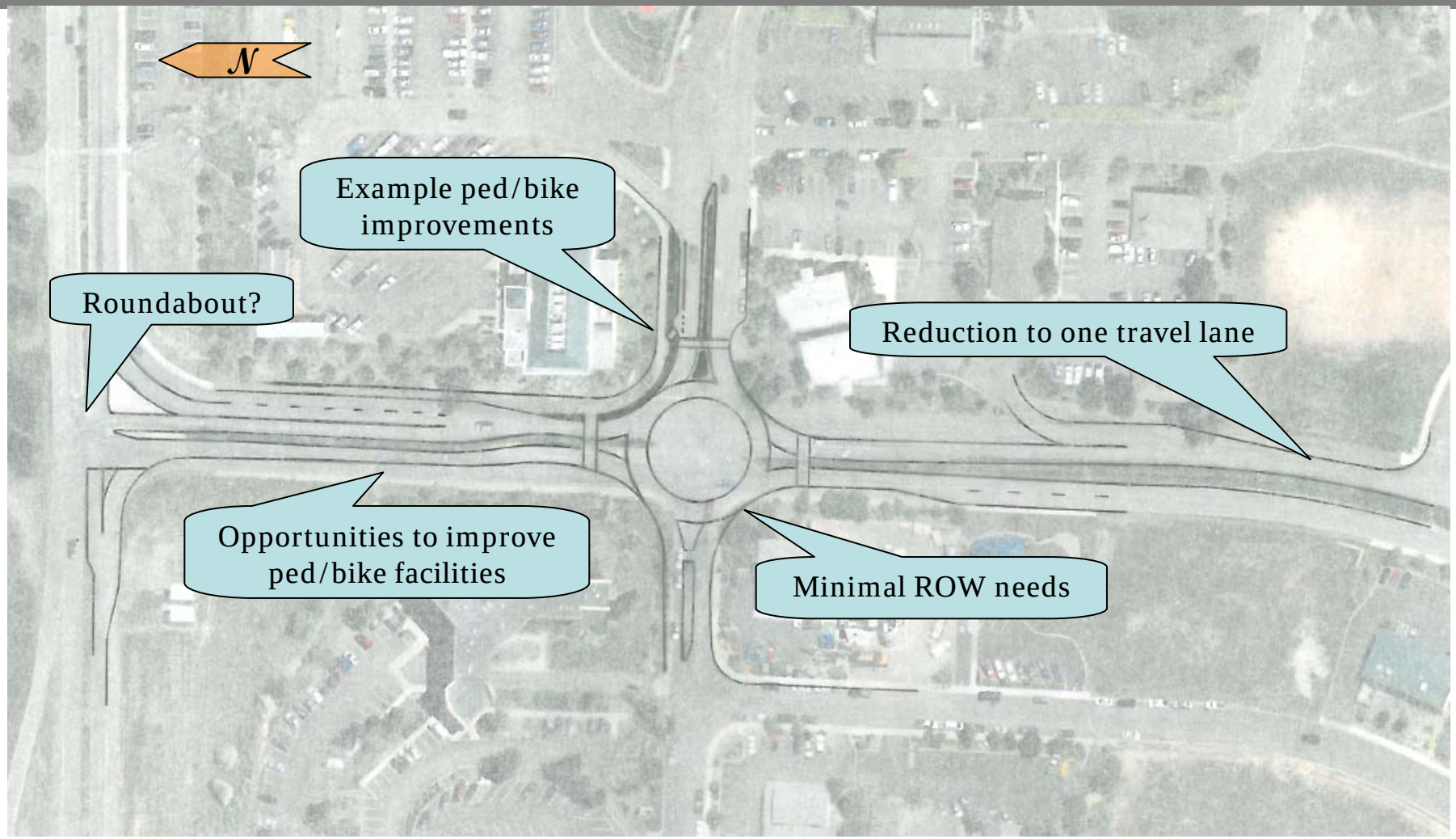
Roundabouts and Driveways

Case Study #1 – Campus Drive/Daggett Avenue

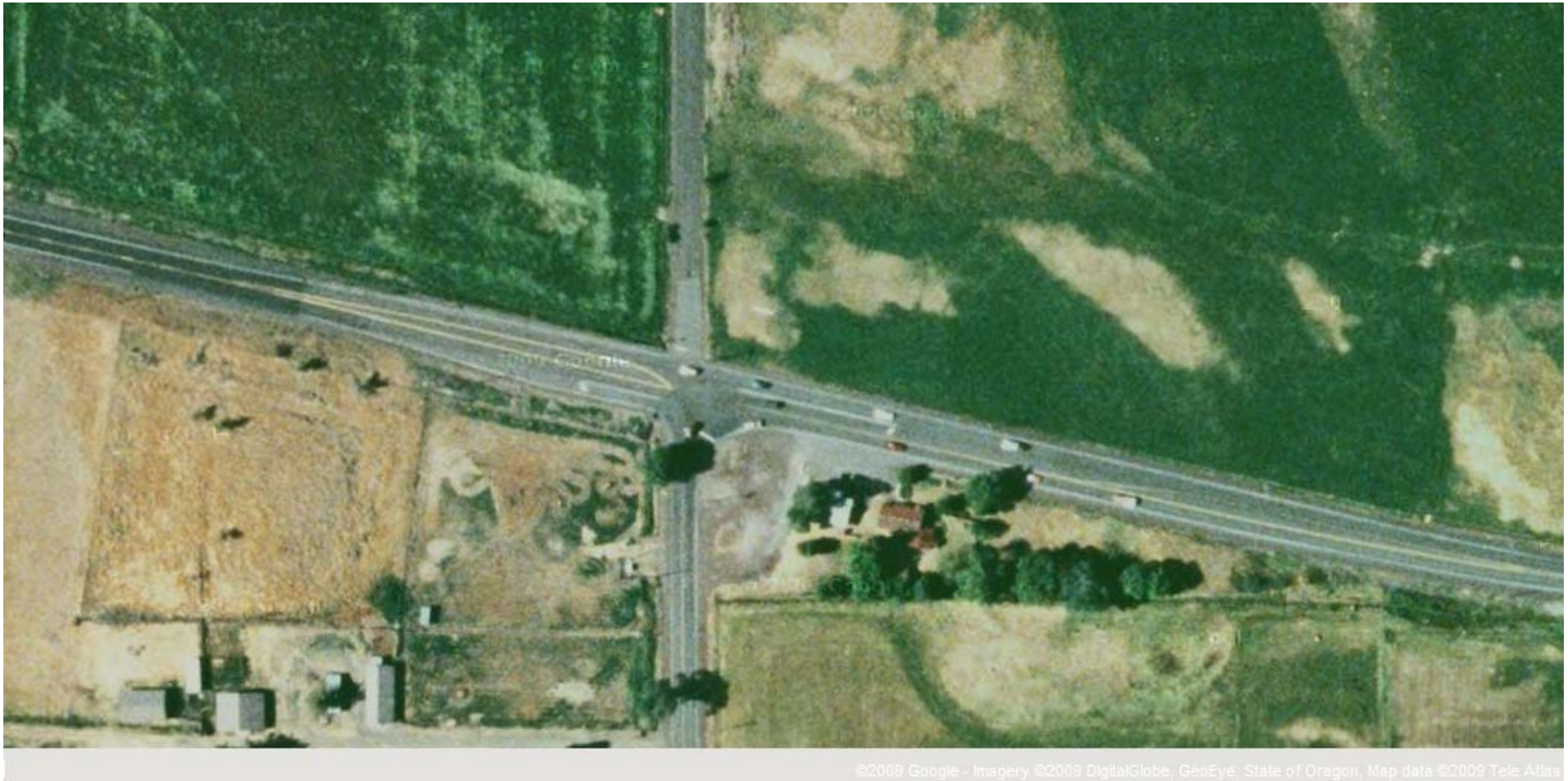
- **Year 2006 Conditions**
  - v/c ratio = 0.77
  - LOS = F
  - 5 years of safety data
    - **13 crashes**
    - **mostly angle crashes**
- **Year 2013 Conditions**
  - Includes OIT Expansion
  - v/c ratio > 1.0 (peak 15 mins)
  - LOS = F
  - Does not meet signal warrants
- **Year 2013 Mitigated Conditions**
  - Single-lane roundabout

	N	S	E	W
v/c	0.47	0.49	0.23	0.08
LOS	A	A	A	A

Case Study # 1 – Campus Drive/Daggett Avenue

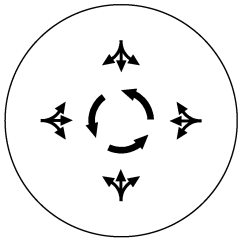
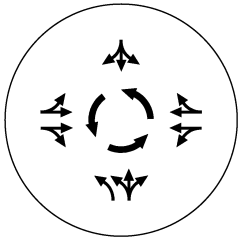
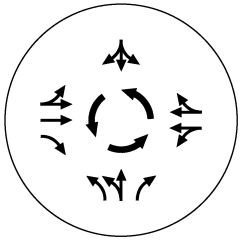


Case Study # 2: OR 126/Powell Butte Highway



Case Study # 2: OR 126/Powell Butte Highway

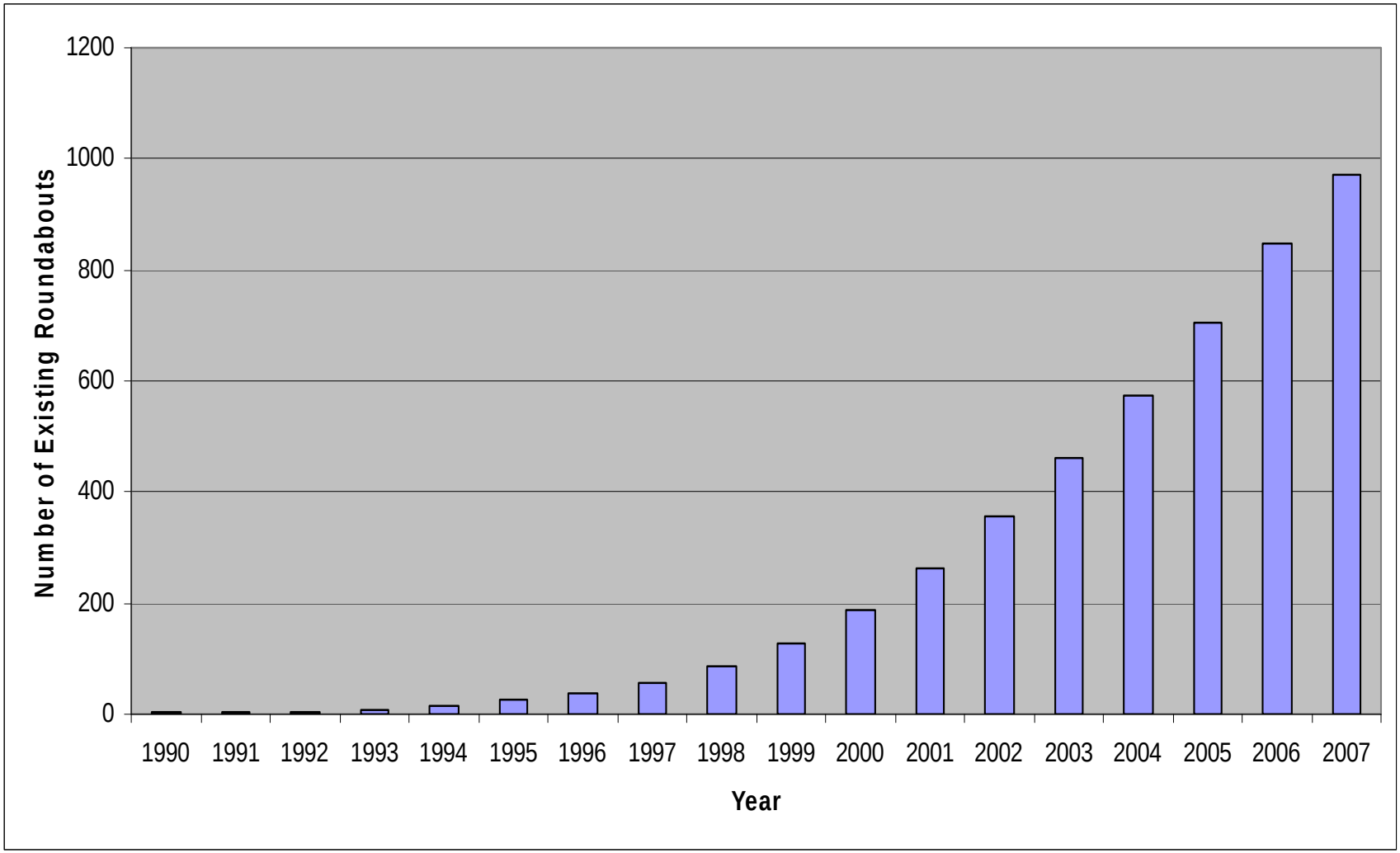
- **Weekday PM Peak**

Lane Configuration	Traffic Operations				
	Year 2010	Year 2015	Year 2020	Year 2025	Year 2030
	V/C = 0.68	V/C = 0.85	Over Capacity	Over Capacity	Over Capacity
	V/C = 0.36	V/C = 0.45	V/C = 0.57	V/C = 0.70	V/C = 0.84
	V/C = 0.33	V/C = 0.36	V/C = 0.41	V/C = 0.48	V/C = 0.54

Case Study # 2: OR 126/Powell Butte Highway

Case Study # 2: OR 126/Powell Butte Highway

Number built each year is going up exponentially

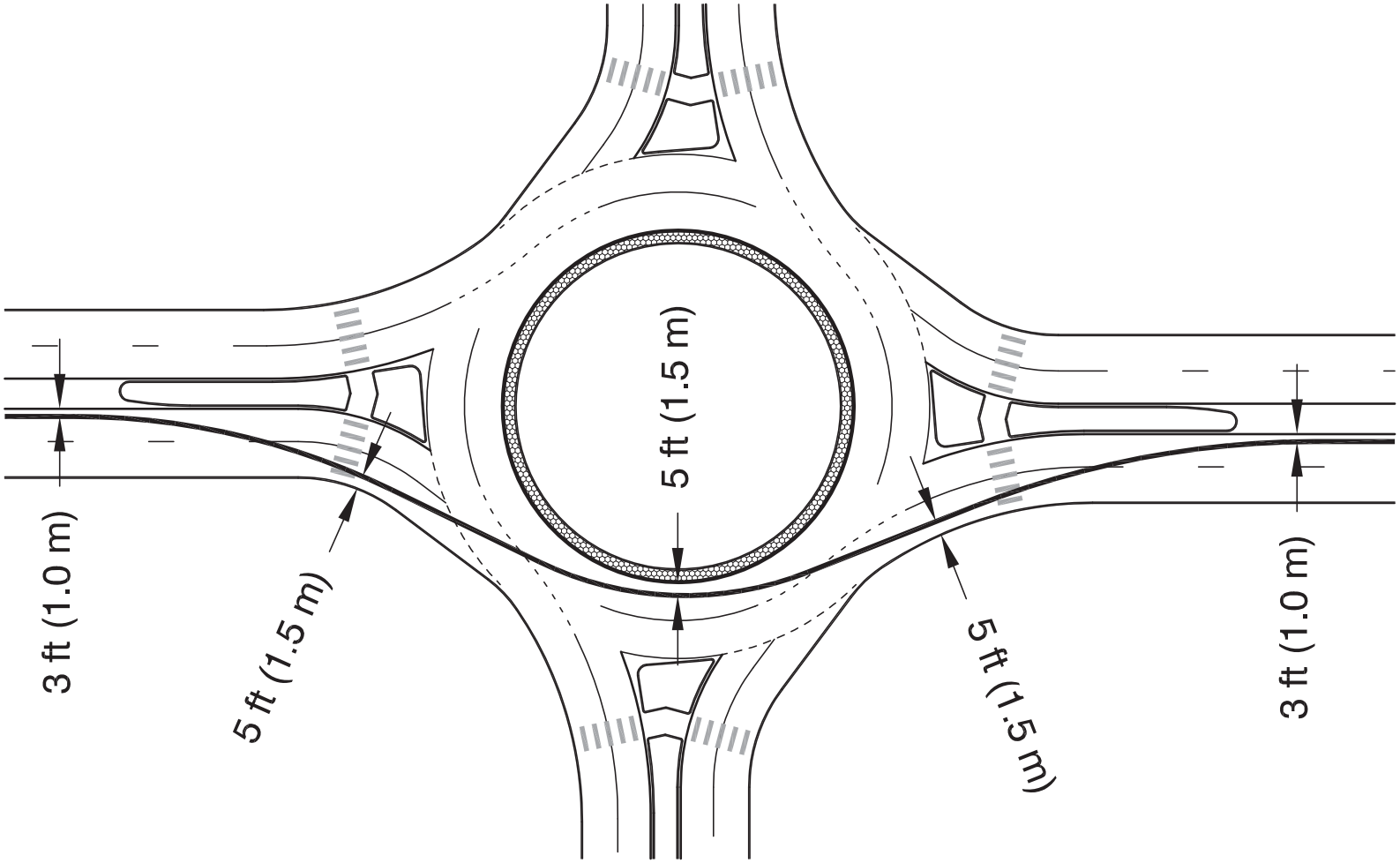


Categories of Roundabouts

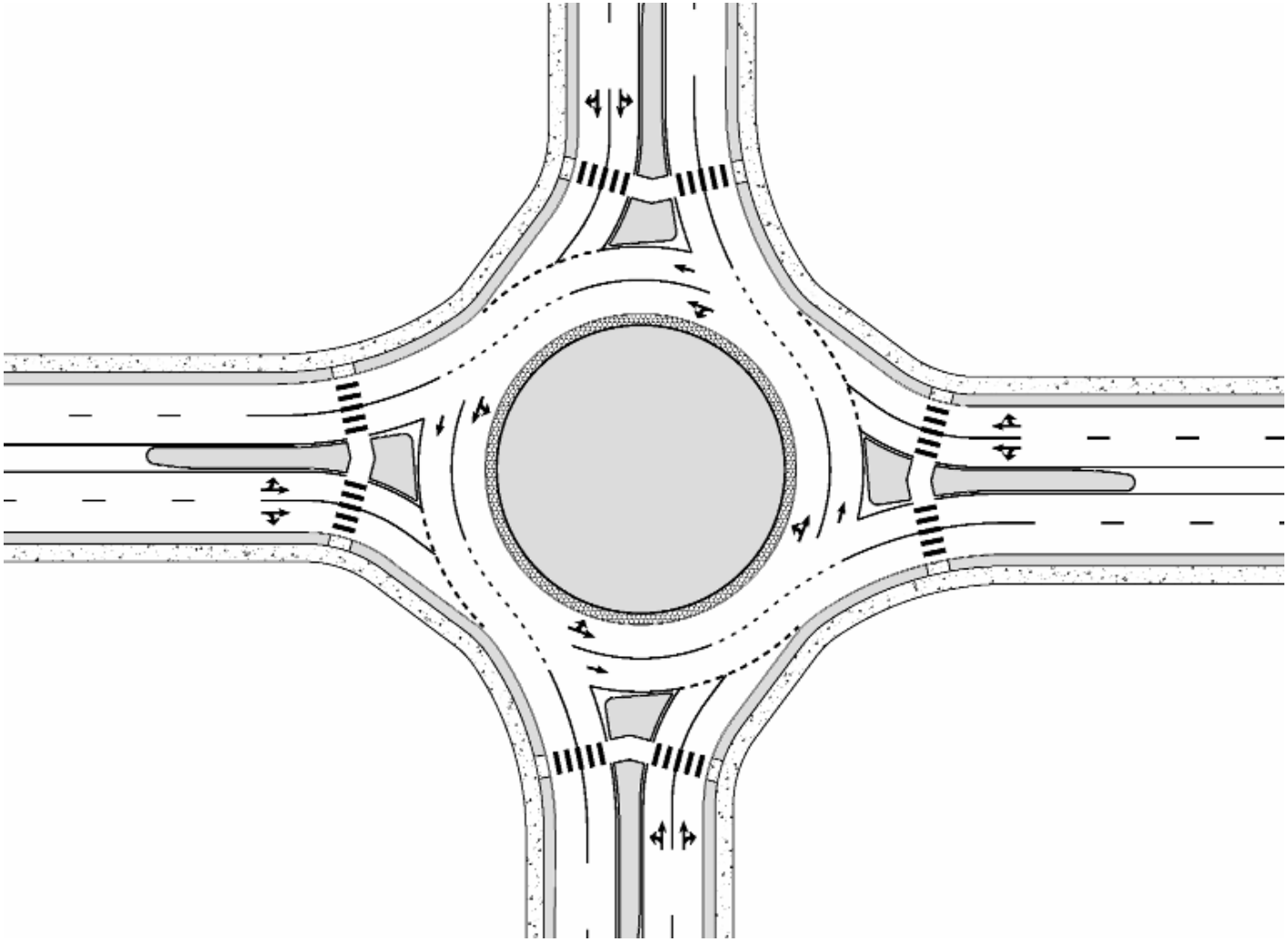
Roundabout Configuration	Typical Design Vehicle	Common Inscribed Circle Diameter Range*
Single-Lane Roundabout	B-40	90 to 150 ft
	WB-50	105 to 150 ft
	WB-67	130 to 180 ft
Multilane Roundabout (2 lanes)	WB-50	150 to 220 ft
	WB-67	165 to 220 ft

* Assumes 90-degree angles between entries and no more than four legs. List of possible design vehicles not all-inclusive.

Speed Profile

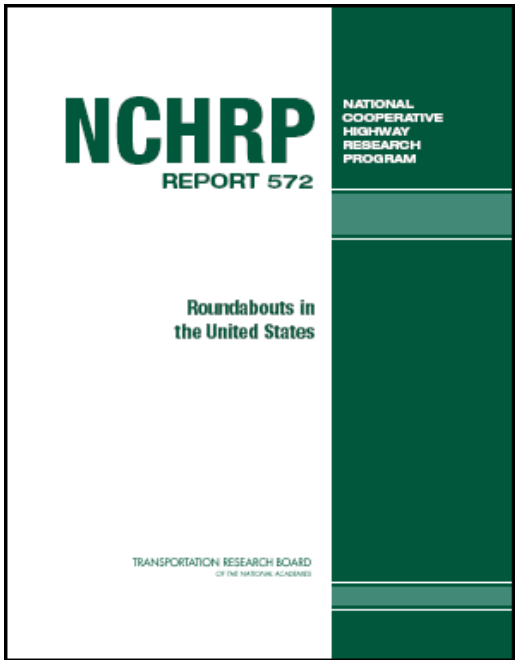


Urban Double-Lane Roundabouts



NCHRP Report 572: Roundabouts in the U.S.

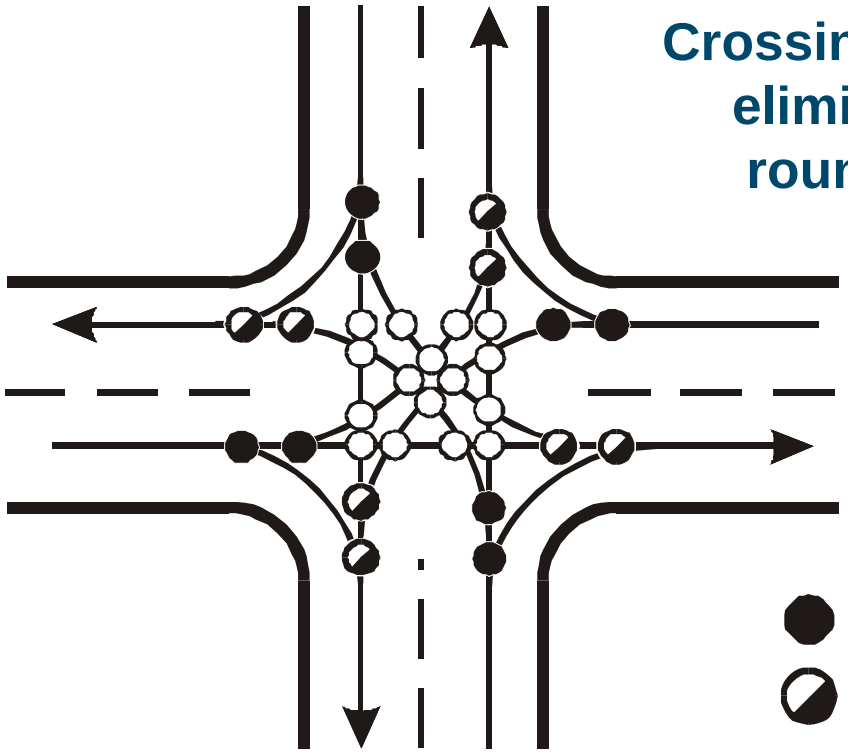
- **NCHRP Project 3-65**
- **Most comprehensive study of U.S. roundabout performance to date**
- **Safety and operational models based on U.S. field data**
- **Updated design guidance based on model findings and current state-of-the-art practice and thinking**
- **Completed May 2006**



U.S. Roundabout Safety Experience
NCHRP Report 572 Results (May 2006)

Previous Intersection Form (sample size)	% Reduction in All Crashes	% Reduction in Fatal/Injury Crashes
All sites (55)	35	76
Signalized (9)	48	78
All-way stop (10)	No significant change	No significant change
Two-way stop (36)	44	82

Vehicle Conflict Points: REDUCED

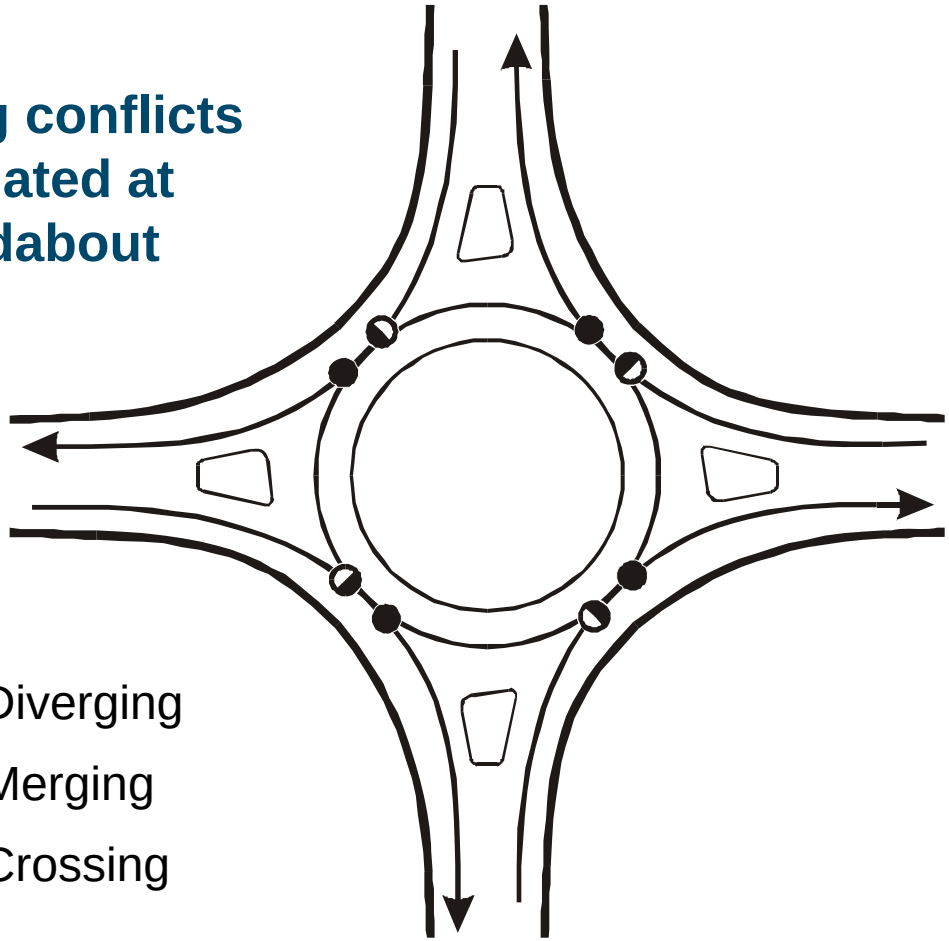


Crossing conflicts eliminated at roundabout

Diverging

Merging

Crossing

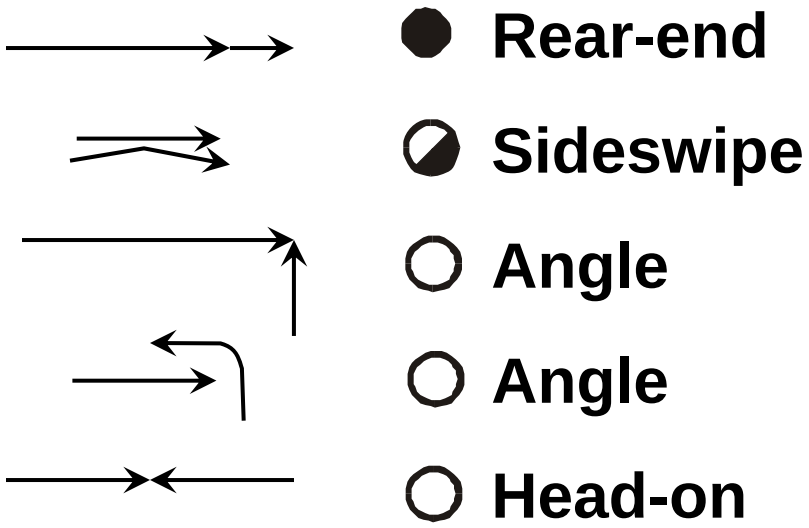


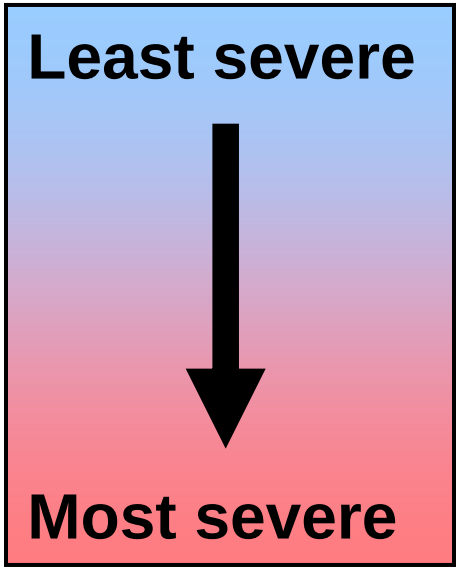
32 conflicts

8 conflicts

Severity of Vehicular Conflicts: REDUCED

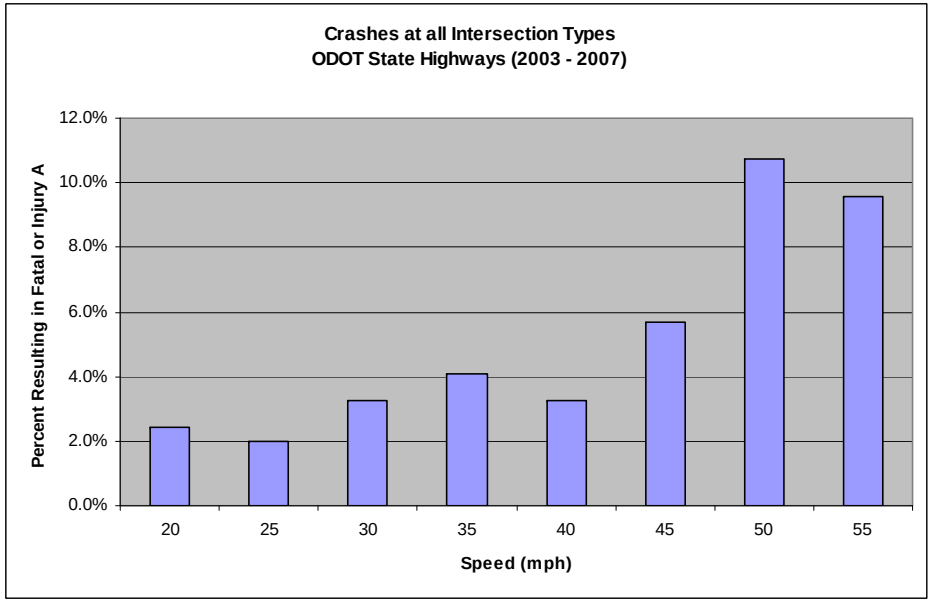
- **Severity related to relative velocities of conflicting streams**

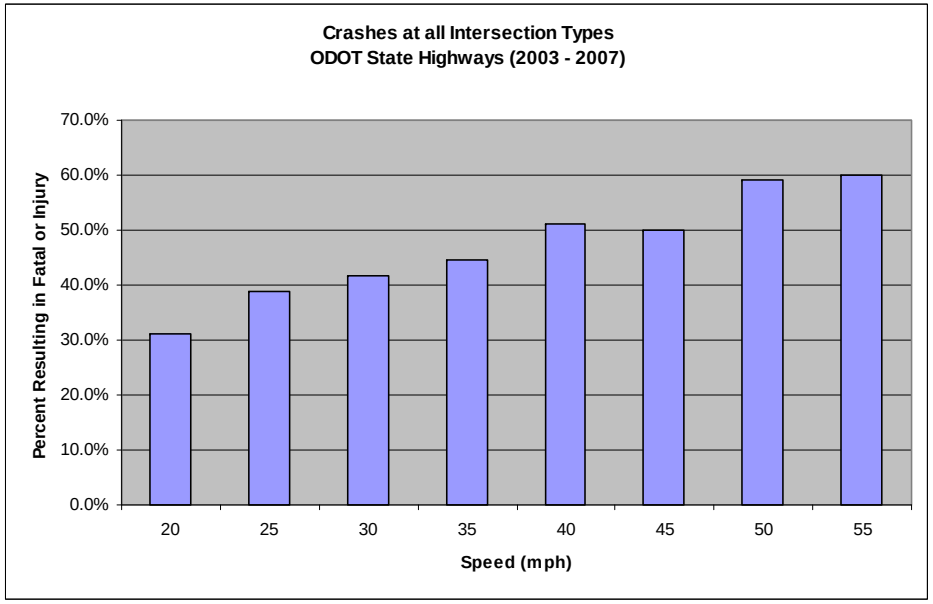




Vehicle speeds: REDUCED

As speeds increase, so does severity of crashes





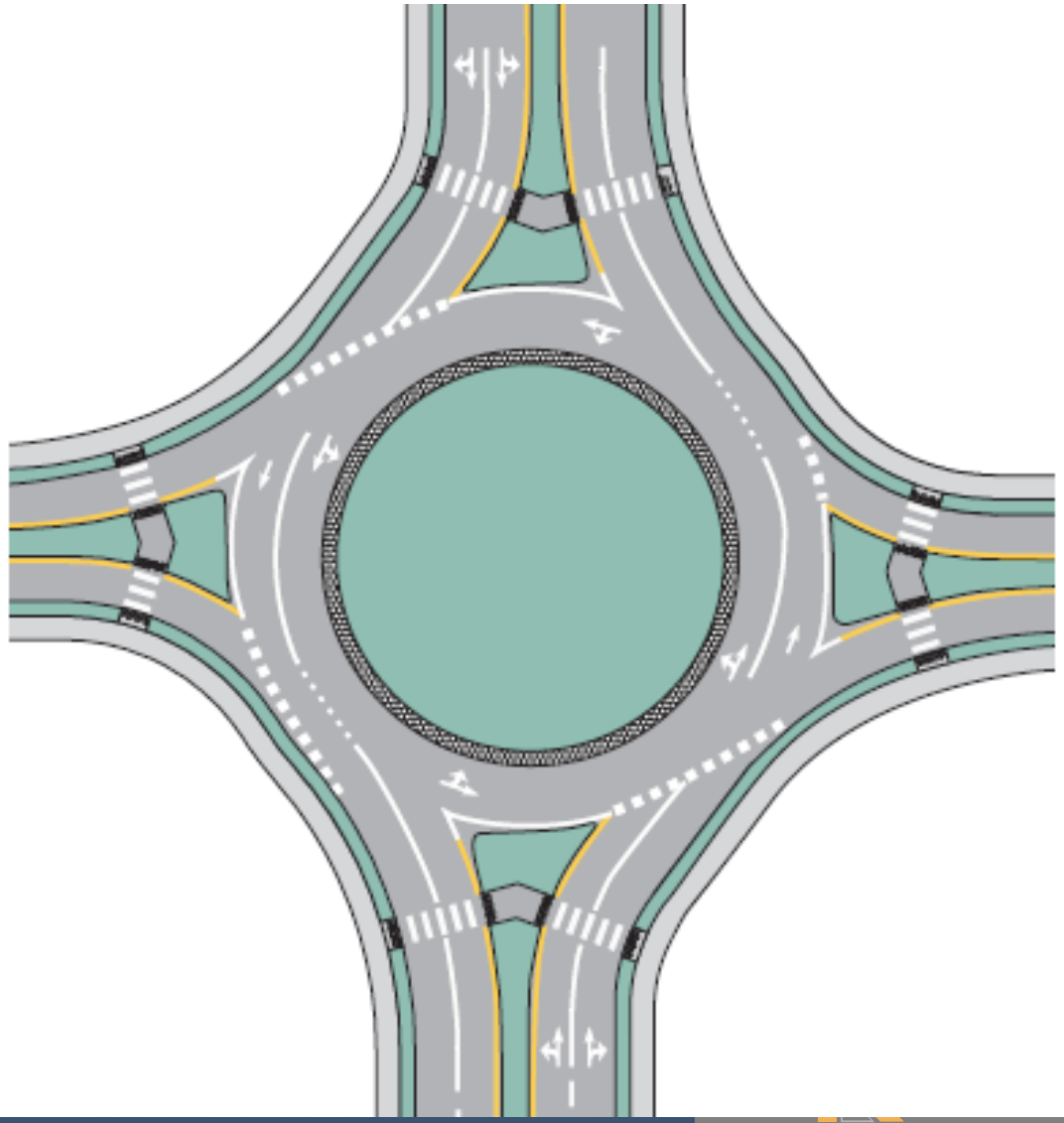
Rationale: Operations

- **Roundabout gives higher capacity and lower delays than AWSC under same conditions**
- **Roundabout likely to have higher delays than TWSC if TWSC is operating without problems**
- **Single-lane roundabout can be assumed to operate within capacity any location where peak hour volume signal warrant not met**
- **Roundabout within capacity will generally produce lower delays than signal under same conditions**

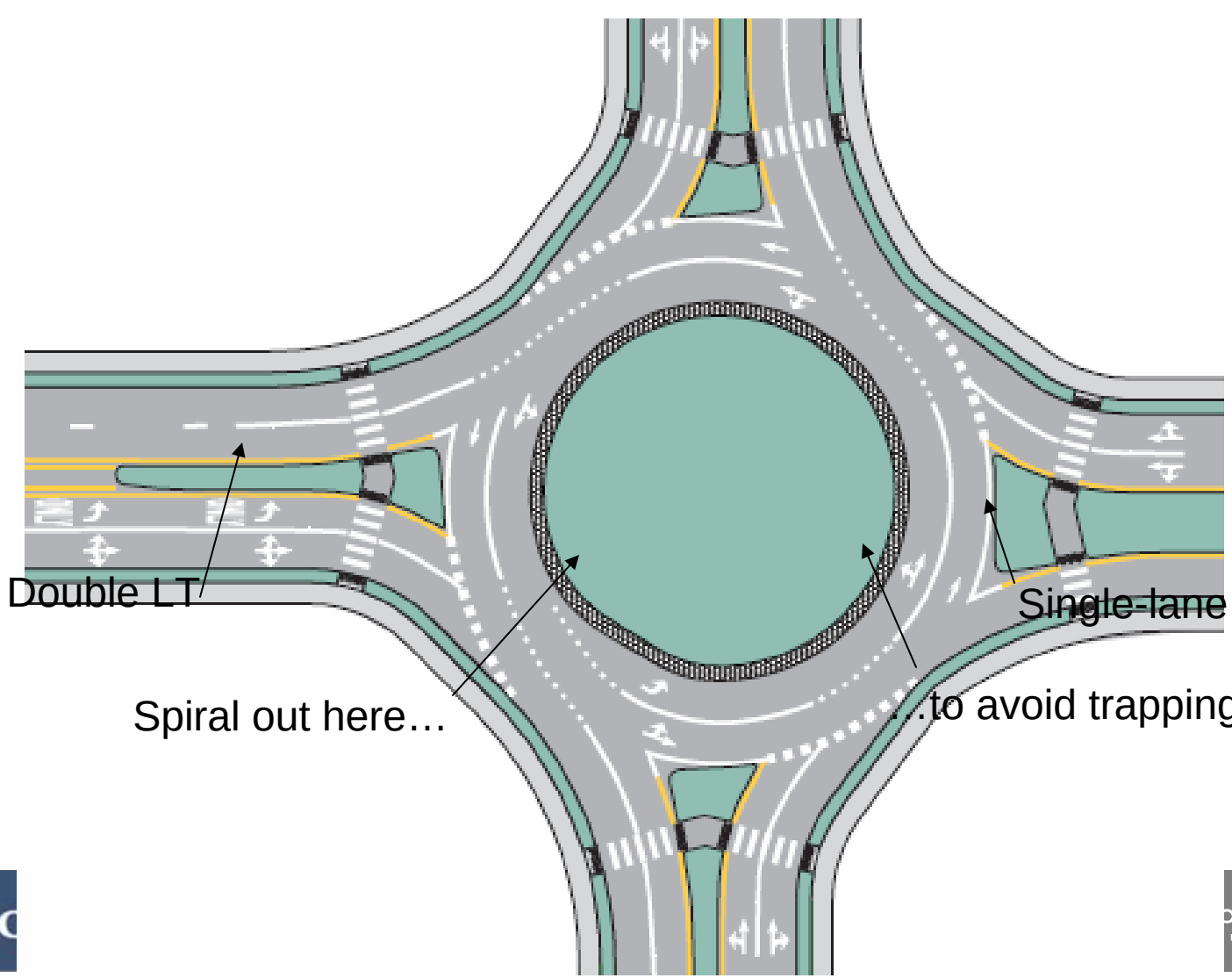
Lane numbers and assignments

- **Each entry, exit, and section of circulatory roadway should have the appropriate number of lanes, properly assigned**
- **Geometric design, signing/striping, and operational analysis need to agree**
- **OK to have mixture of single- and multi-lane entries**

Example of 2-Lane with 1-Lane Side Street



2-Lane Rdbt with Double-Left Turn



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