Roundabout Design 101:
Principles, Process, and Documentation

Part 1
March 7, 2012

Well designed roundabouts should minimize accidents, delay and costs for everyone using the intersection. This session covers the design process that leads to a well designed roundabout as well as challenging conditions where roundabouts may fail.

Presentation Outline – Part 1

- Identifying Candidate Intersections
- Evaluation Process
- Safety Performance
- Design Principles
- Balanced Design
- Design Composition
  - What can go wrong?

Presentation Outline – Part 2

- Geometry and Capacity
- Choosing a Capacity Analysis Method
  - Modeling differences
    - Capacity
    - Delay
    - Limitations
- Variation / Uncertainty in Prediction
- Examples
- Staging Construction to Match Volume Increase

Modern Roundabout Benefits

- Superior safety performance
- Very high capacity … up to 6,000 VPH
- Great geometric flexibility – ROW
- Simple for traffic to use
- Simple for pedestrians to use
- Environmental benefits
- Aesthetic .. can look superb .. Civic Feature

Where to Consider Roundabouts

- Intersections with high crash rates/high severity rates
- Intersections with complex geometry, skewed approaches, >4 approaches
- Rural intersections with high-speed approaches
- Freeway interchange ramp terminals
- Closely spaced intersections
- Replacement of all-way stops
- Replacement of signalized intersections
- At intersections with high left turn volumes
- Replacement of 2-way stops with high side-street delay
- Intersections with high U-turn movements
- Transitions from higher-speed to lower-speed areas
- Where accommodating older drivers is an objective

Evaluate Alternatives

- Do Nothing
- Install Traffic Signals
- Install Roundabout
- Other options (DDI?)

- Primary MOE's:
  - – Cost
  - – Safety
  - – Capacity

Secondary MOE's:

- Environmental factors of air, fuel and time

Signal vs. Roundabout

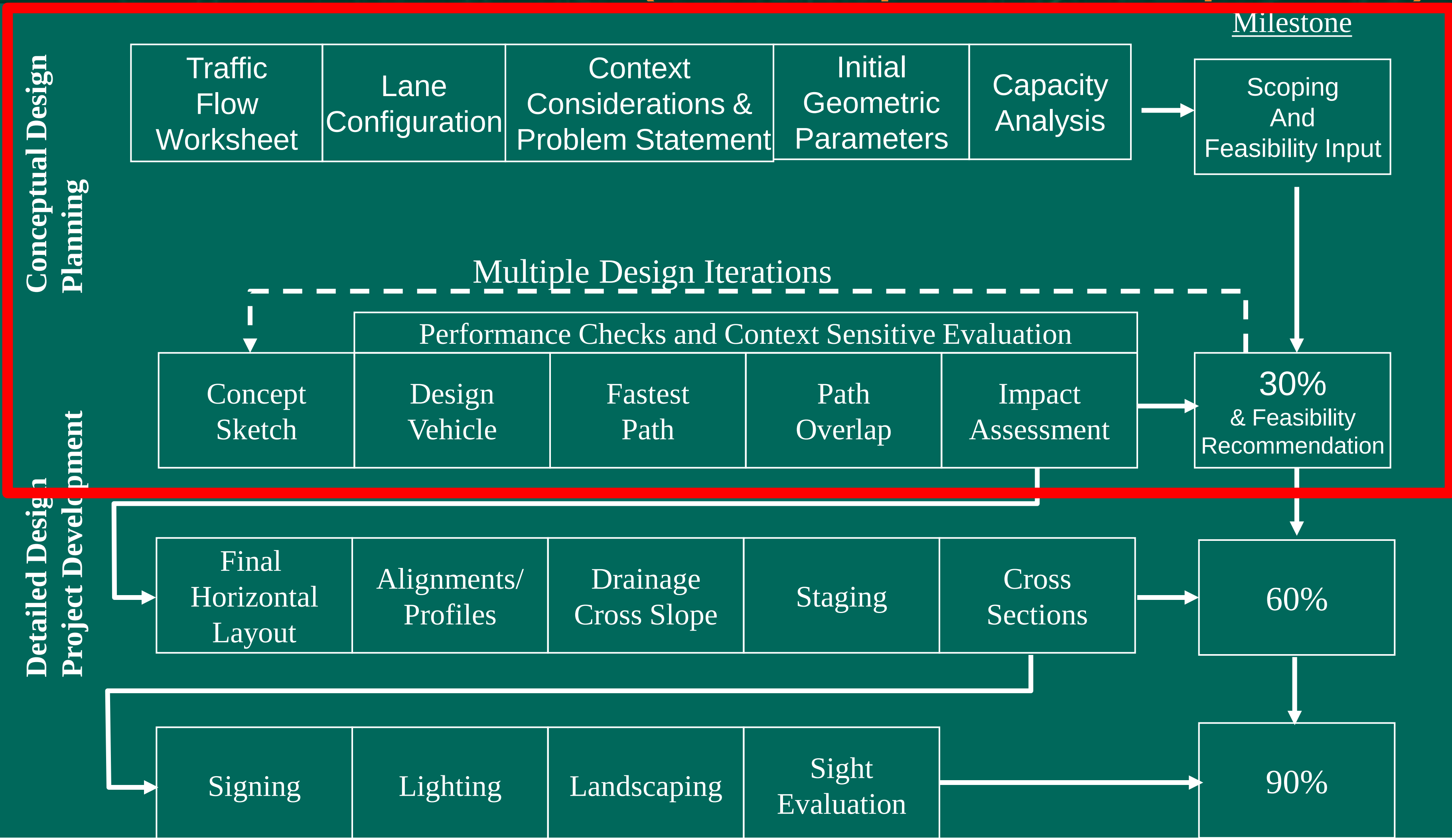
Intersection Control Study Contents

1. Project Background - describe site conditions
2. Safety Assessment (historical crash data)
3. Operational Analyses – Arcady, HCM
4. Cost Comparison – Construction, crash savings, life-cycle
5. Alternative Selection – screening criteria (capacity, safety, cost)
6. Conceptual Roundabout Design – nearly a 30% design
7. Conclusions and Recommendations

The Key Mindset:

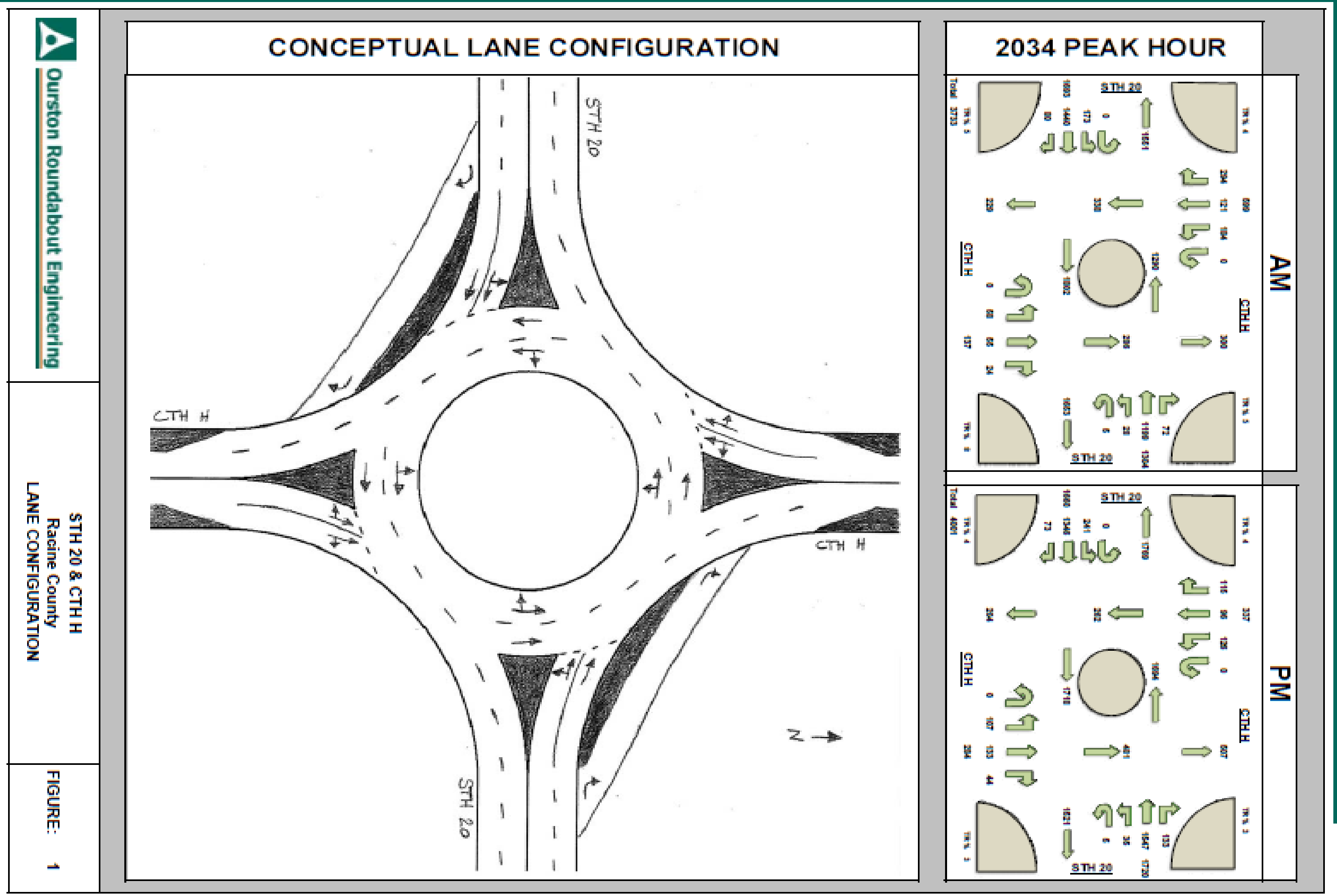
- Be sure to solve a problem if a roundabout is to be used!

Substantial Design Effort for Intersection Control Studies (Concept Development)



Design Inputs – Traffic Forecasts

"Model it first, draw it next"



Existing and Future Operations

Alternative	2013 LOS (AM/PM)	2033 LOS (AM/PM)
Existing two way stop (CTH F LOS)	C (22.5)/F (86.0)	E (42.5)/F (425.5)
Traffic Signal	Not Evaluated	B (10.6)/B (12.3)
Roundabout	Not Evaluated	A (6.0)/A (6.9)

- Reduced delay = reduced vehicle emissions

Collision Cost Assessment

Crash Severity	Economic Cost per Crash (2008 dollars)
Fatality	$4,200,000
Class A (incapacitating injury)	$214,200
Class B (non-incapacitating evident injury)	$54,700
Class C (possible injury)	$26,000
Property Damage Only (per crash)	$2,400

Source: National Safety Council (*7*)

Note: Different figures are used for HSIP applications

Roundabout collisions = low severity (failure to yield)

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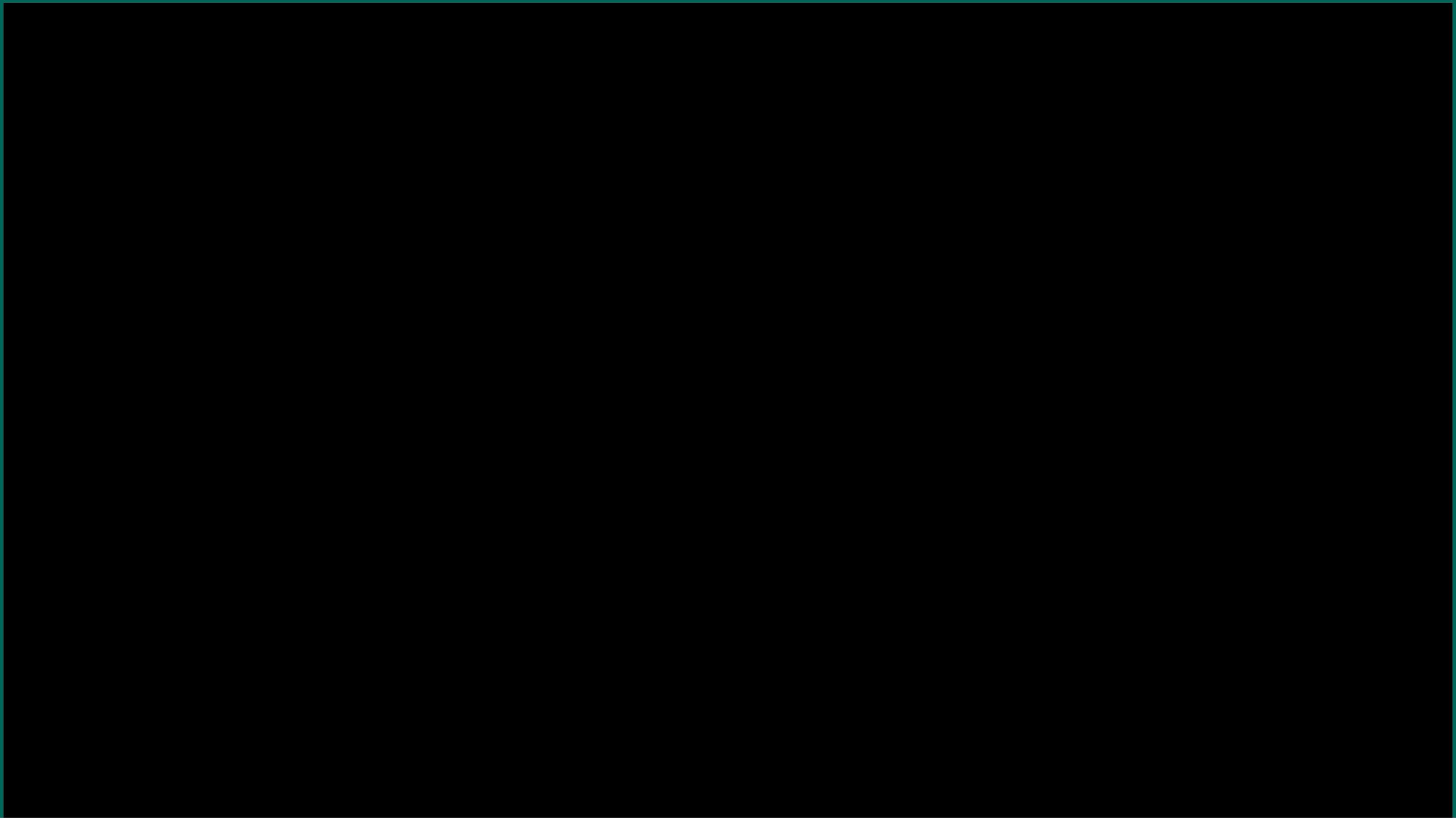


Comprehensive Evaluation of Wisconsin Roundabouts

Wisconsin Traffic Operations and Safety Laboratory, September 2011

- 24 roundabouts built before 2008
- 3 years before/after crash data
- Results based on Empirical Bayes adjustment
- Mixed results for total crash frequency
- 9% decrease in total crashes
- Significant 52% decrease in injury crashes
  - Speed limit did not show significant impact on safety
  - Multi-lanes seem to be safer than single lane roundabouts for injury crashes
  - Single lanes saw the largest decrease in total crashes

Comprehensive Evaluation of Wisconsin Roundabouts

Simple Distribution (before EB adjustment)
3 yrs before / 3 yrs after crash data

TABLE 4 Distribution of Crash Types and Severity for All Roundabouts

Collision Type	Before						After					
	K	A	B	C	PD	Total	K	A	B	C	PD	Total
ANGL	1	4	16	26	72	119		2		3	49	54
HEAD			2	2		4					1	1
NO C	1	1	2	2	29	35			9	4	64	77
REAR			5	13	37	55		1	1	13	39	54
SSOP				3	3	6					1	1
SSS			1	1	8	10		1	1	6	67	75
Total	2	5	26	47	149	229		4	11	26	221	262

Crash Type

= Significant Reduction in Economic Cost

Typical Quantitative Comparison

Item	Traffic Signals	Roundabout
Total Construction Cost	$1,095,000	$1,262,000
Property Acquisition	$140,000	$320,000
Injury Crash Cost (PC)	$905,000	$316,000
Traffic Signal Annual Maintenance and Replacement (PC)	$184,000	-
Additional Street Lighting and Annual Maintenance (PC)	-	$33,000
Total Cost	**$2,324,000**	**$1,931,000**

Evaluation Criteria	Traffic Signals	Roundabout
Annual Injury Crashes by 2027	2.6	0.9
Traffic Operations by 2027	LOS 'C' to 'D'	LOS 'B'
Total Capital Costs	$1.1 million	$1.3 million
Capital plus Life Cycle Costs	$2.3 million	$1.9 million

Typical Qualitative Comparison

Evaluation Criteria	Comments	
	Traffic Signals	Roundabouts
Vehicle Noise, Fuel Consumption and Emissions	Status quo.	Reductions in proportion to reductions in average delay – about 60 percent in the AM and PM peak hours.
Speed Control	Traffic speeds controlled only during red phase. Higher operating speeds on minor road.	Potential to control speeds at all times.
Pedestrians and Persons with Disabilities	May require push-button actuation. Audible signals possible.	Shorter crossing distances, and splitter islands provide refuge. Audible signals possible on individual legs.
Bicyclists	Crossing and left turn movements not accommodated under actuated control.	Lower motor vehicle speeds good for bicyclists.
Emergency Services, Transit	Pre-emption equipment may be required.	Comparable to traffic signals having pre-emption.
Truck Movements	Provides optimal operations on green, but lower operating speeds otherwise.	Good operations for all turning movements.

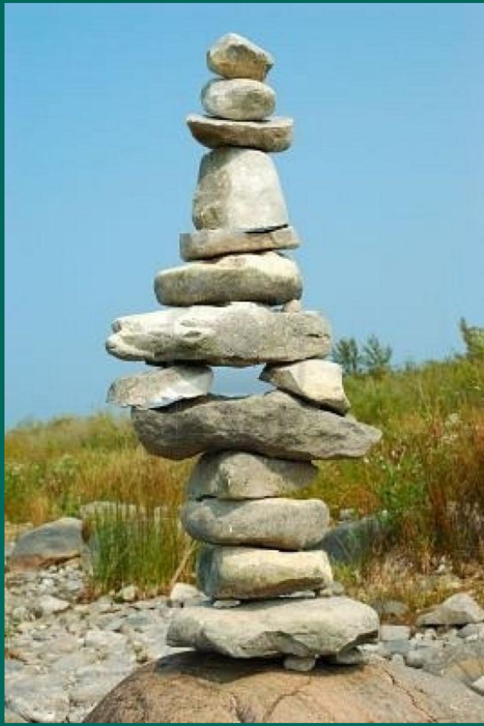
Factors affecting the outcome of these studies:

- What is the year chosen for the life-cycle cost?
- Discount factors
- Collision costs
- Societal costs versus agency costs
- Accuracy of secondary factors (emissions, etc.)
- Decision Environments

Balanced Design Composition

- Good designs should minimize:
  - ➢Accidents (Safety)
  - ➢Delay
  - ➢Costs

- For all who use the intersection:
  - ➢Vehicles (cars, trucks, motorcycles…)
  - ➢Bicyclists
  - ➢Pedestrians



Balancing Competing Objectives

I-70 / Edwards, CO Interchange

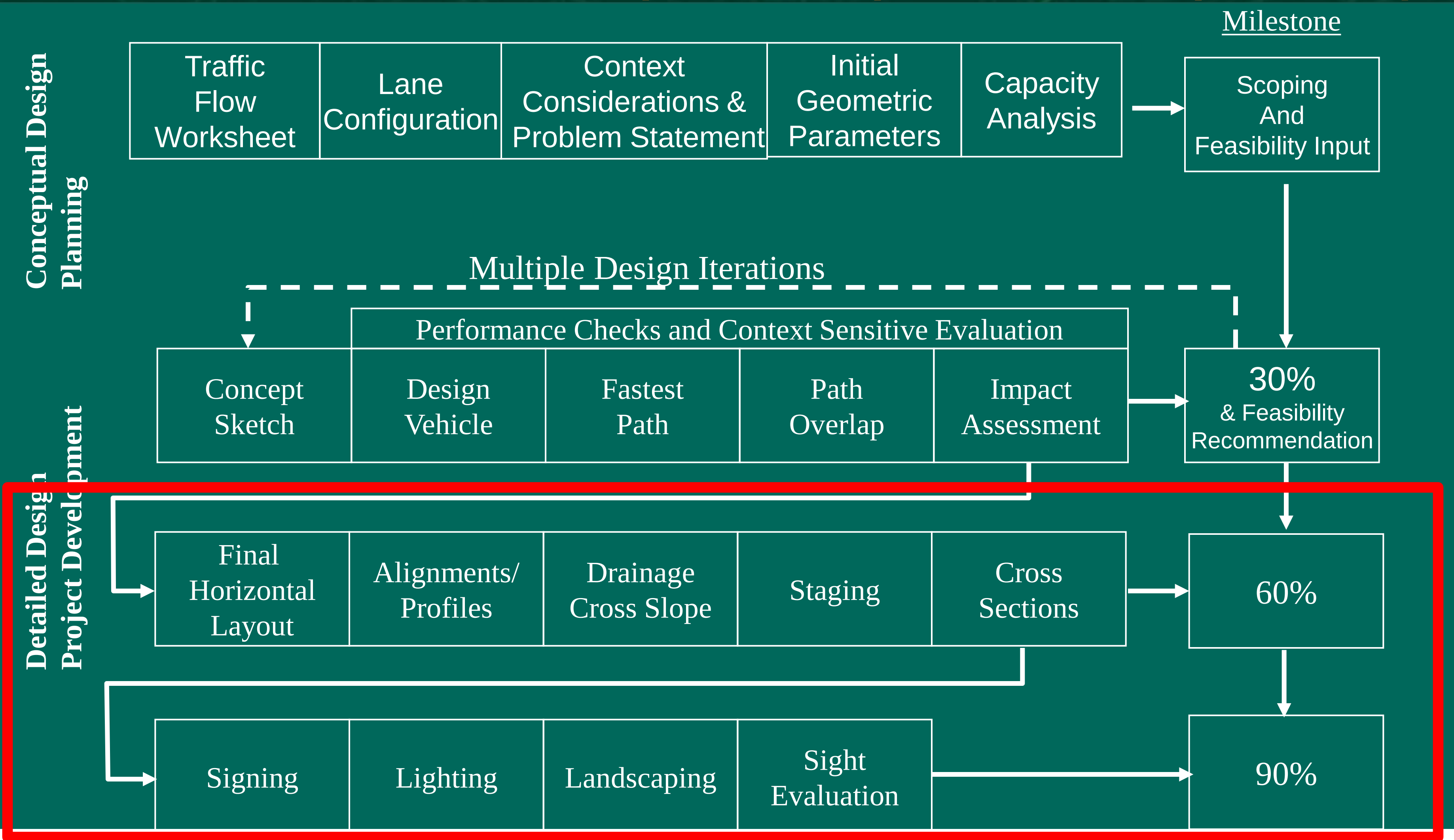
Design Principles

1. Composition (Strategic):
   - Traffic and lane configuration
   - Space for trucks
   - Stopping sight distance
   - Entry and exit paths (overlap for multi-lane)

2. Details:
   1. Grading
   2. Intersection sight distance
   3. Lighting, signs, markings and cross walks

We generally spend more of our time on this.

Substantial Design Effort for Intersection Control Studies (Concept Development)



Performance Based Design
with context consideration

- Speed Reduction
  - Entry Path Curvature
- Vehicle Paths
  - Entry Path Overlap
  - Exit Path Overlap
  - Instinctive Paths
- Traffic Information System
- Sight Distance
- Truck Accommodation
- Design Details

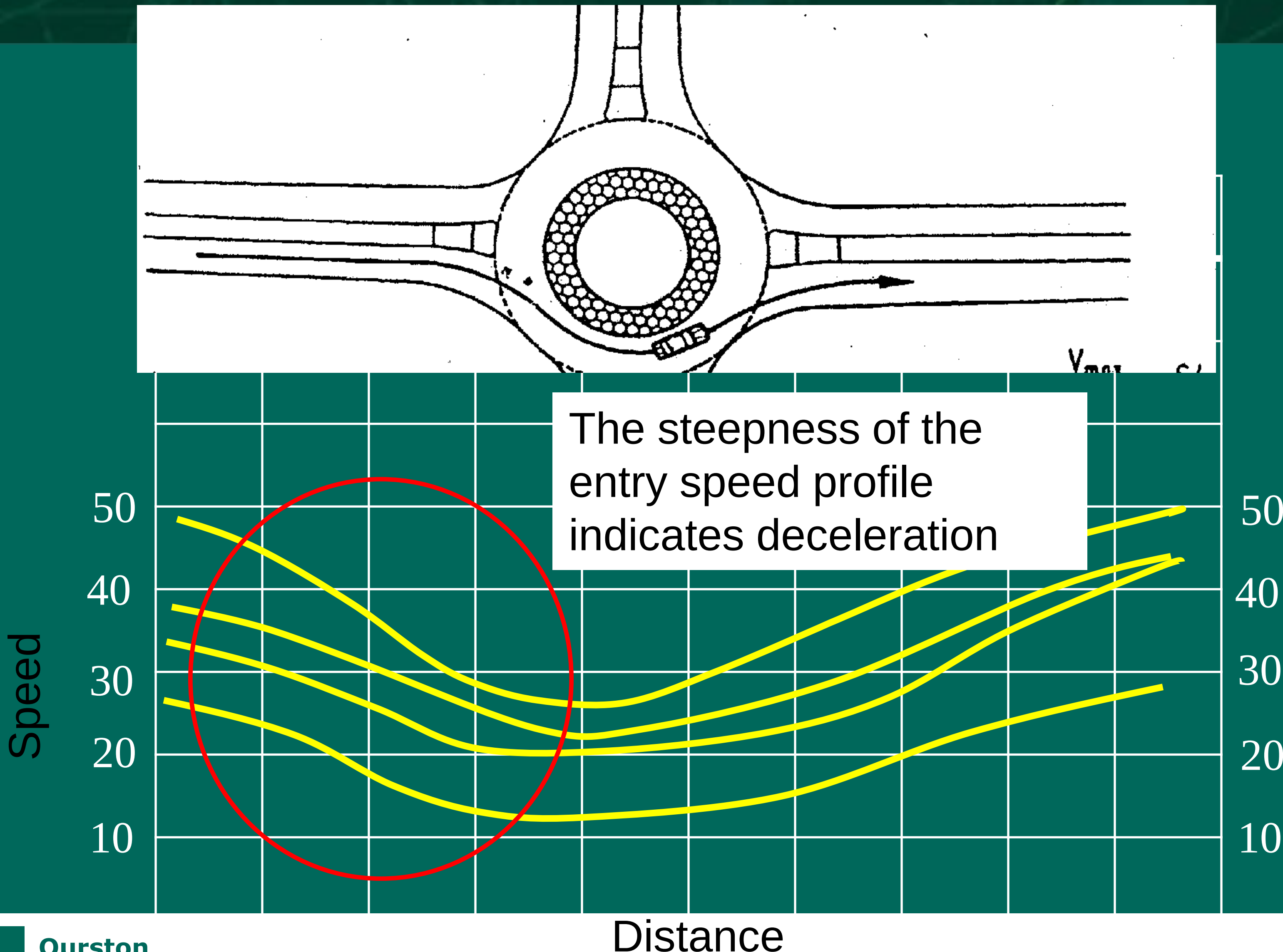
Composition involves synthesizing all of these elements

Safety Issue #1
Inadequate Entry Path Deflection

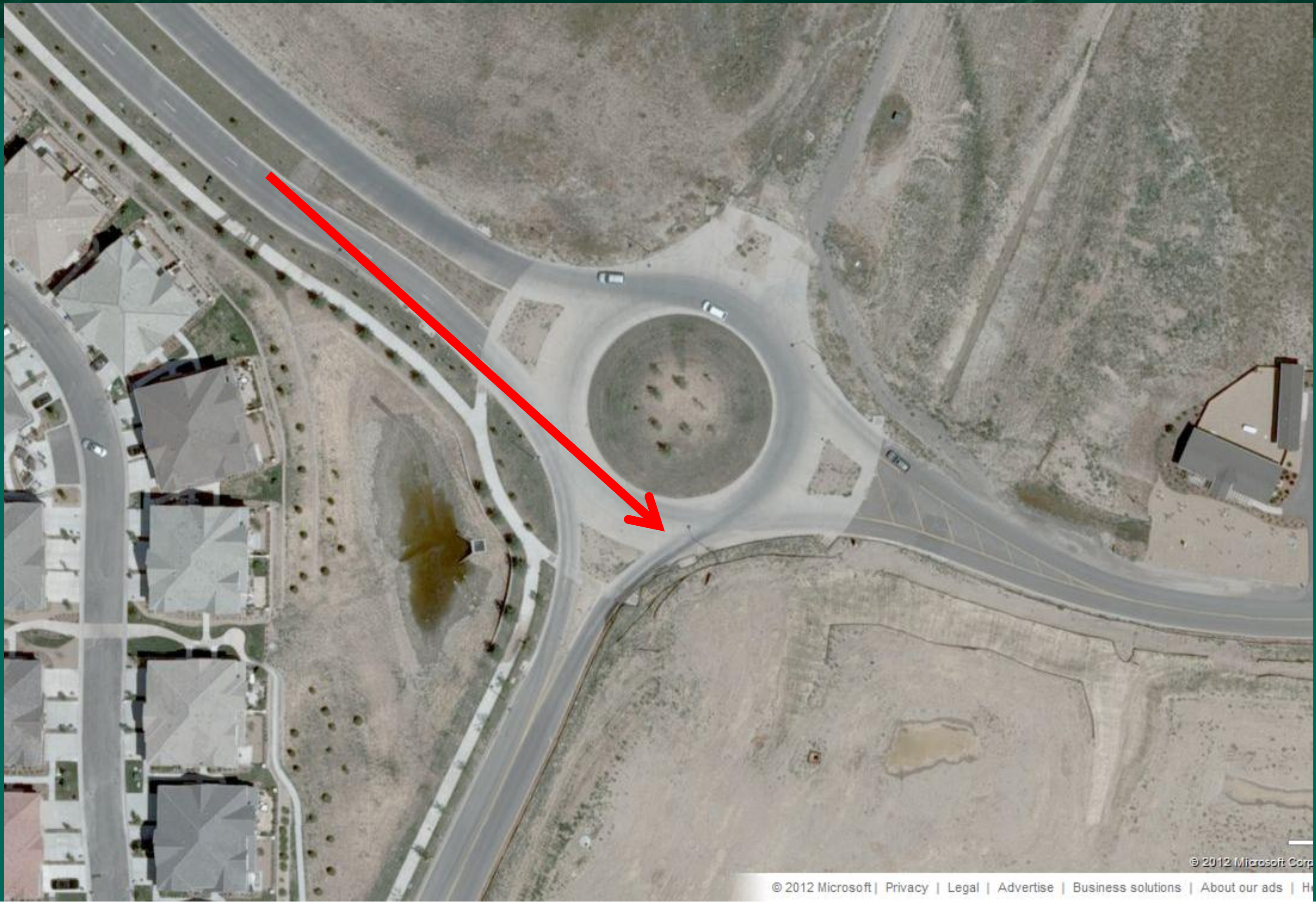
RESULTS:

- Speed of entry too fast
- Impacts pedestrian safety
- Entry / circulating crashes

Speed Profile



Inadequate Speed Control



What is the design entry speed?

Entry speed is not defined by markings

Ways to Achieve Deflection

1. Approaching lanes offset to left of circle's center
2. Circle size
3. Compactness of entry curve combinations

Note: Too much deflection can lead to reduced safety, e.g. SMV crashes

Entry Deflection

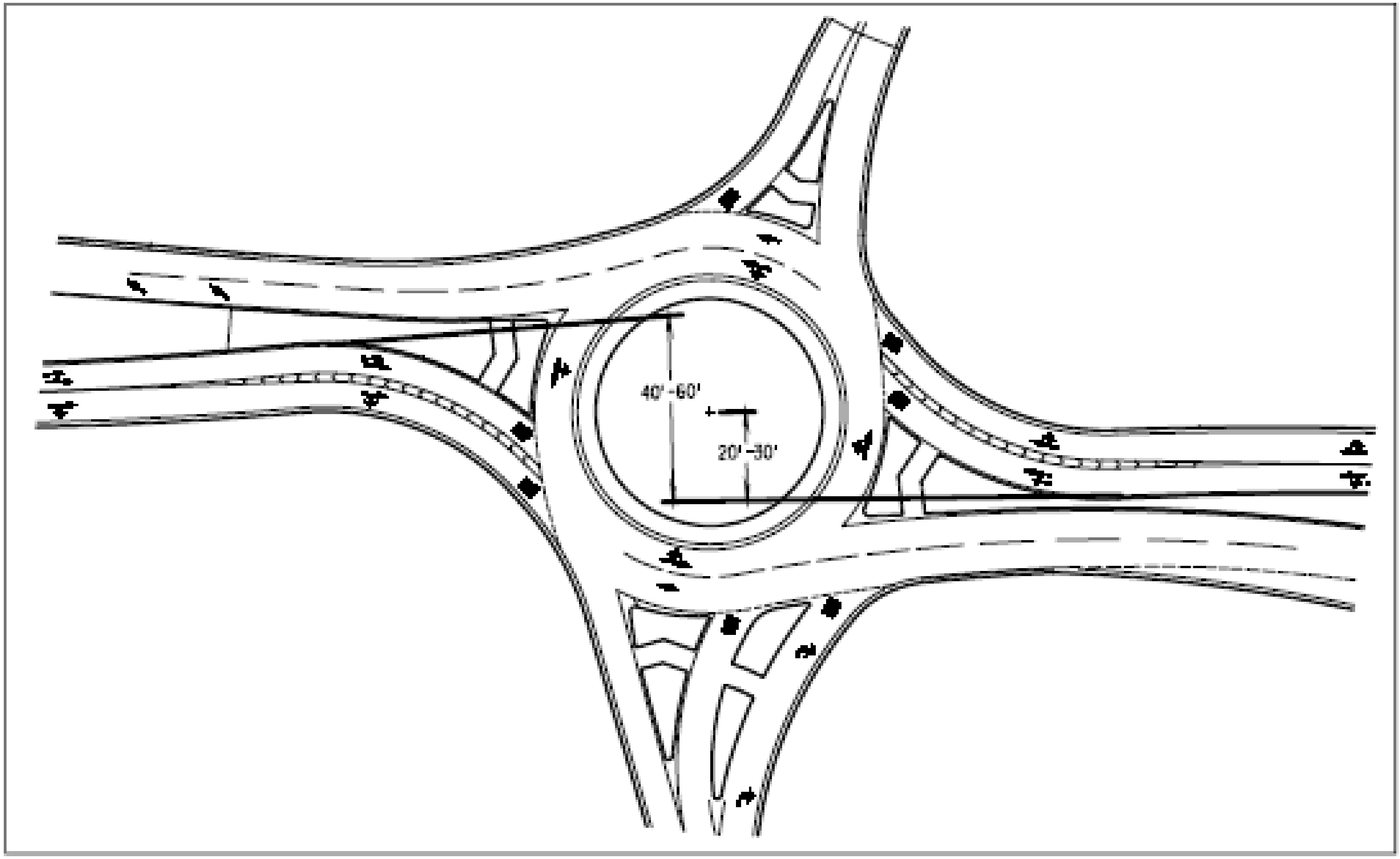
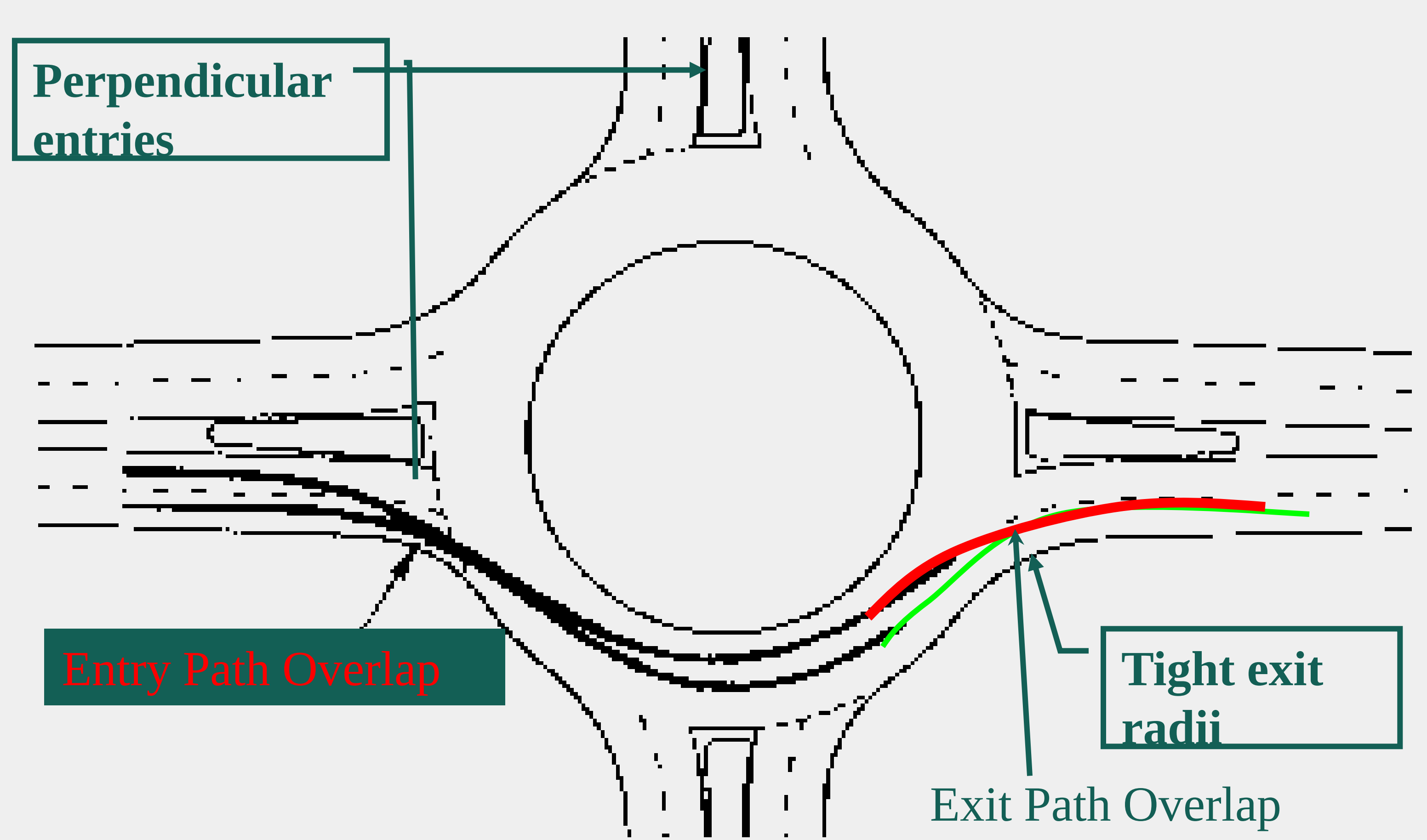


Figure 30.3. Entry Deflection

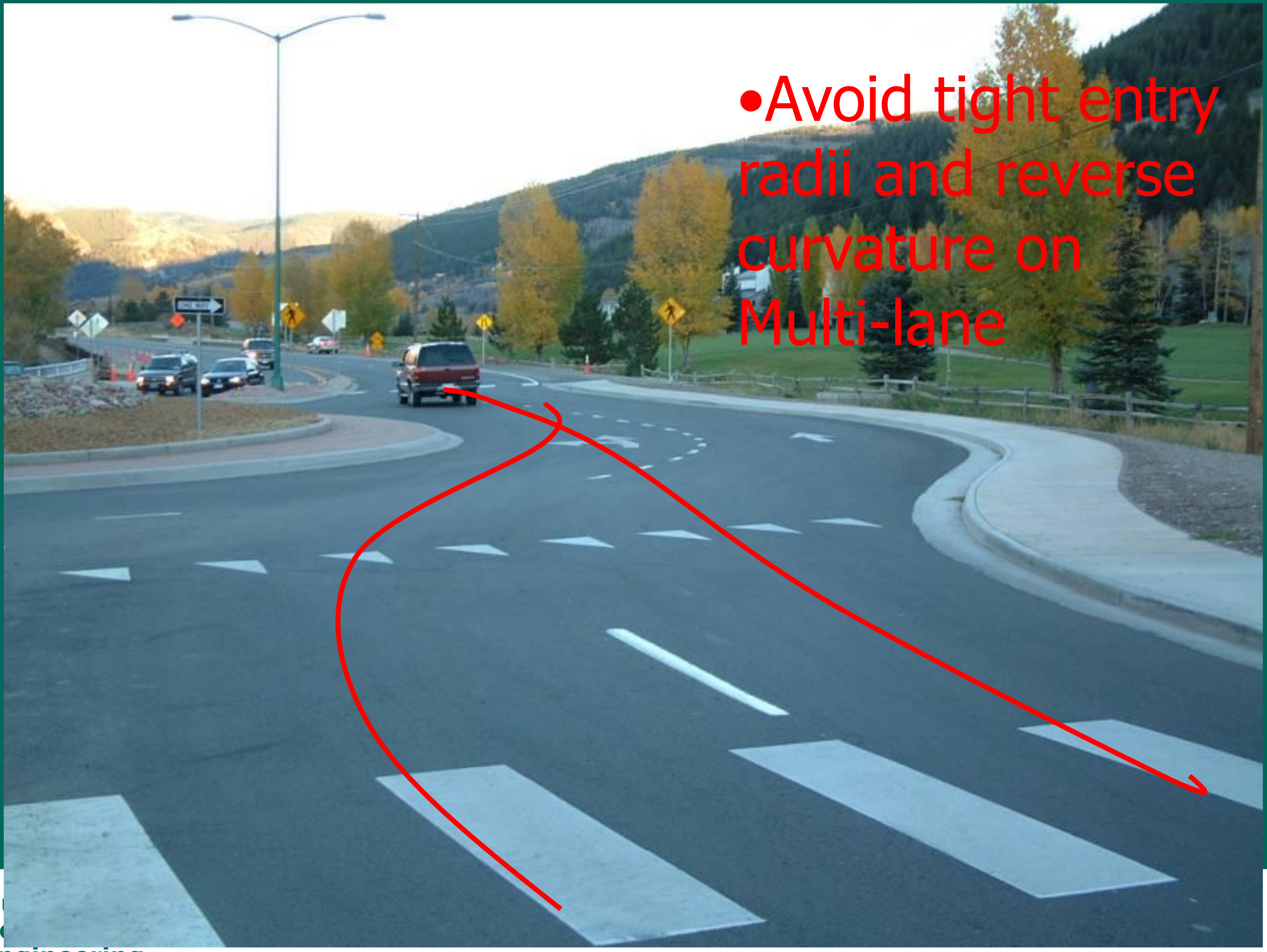
Problems with Guidance

Safety Issue #2: Entry/Exit Path Overlap



Source: FHWA Guide with Edits

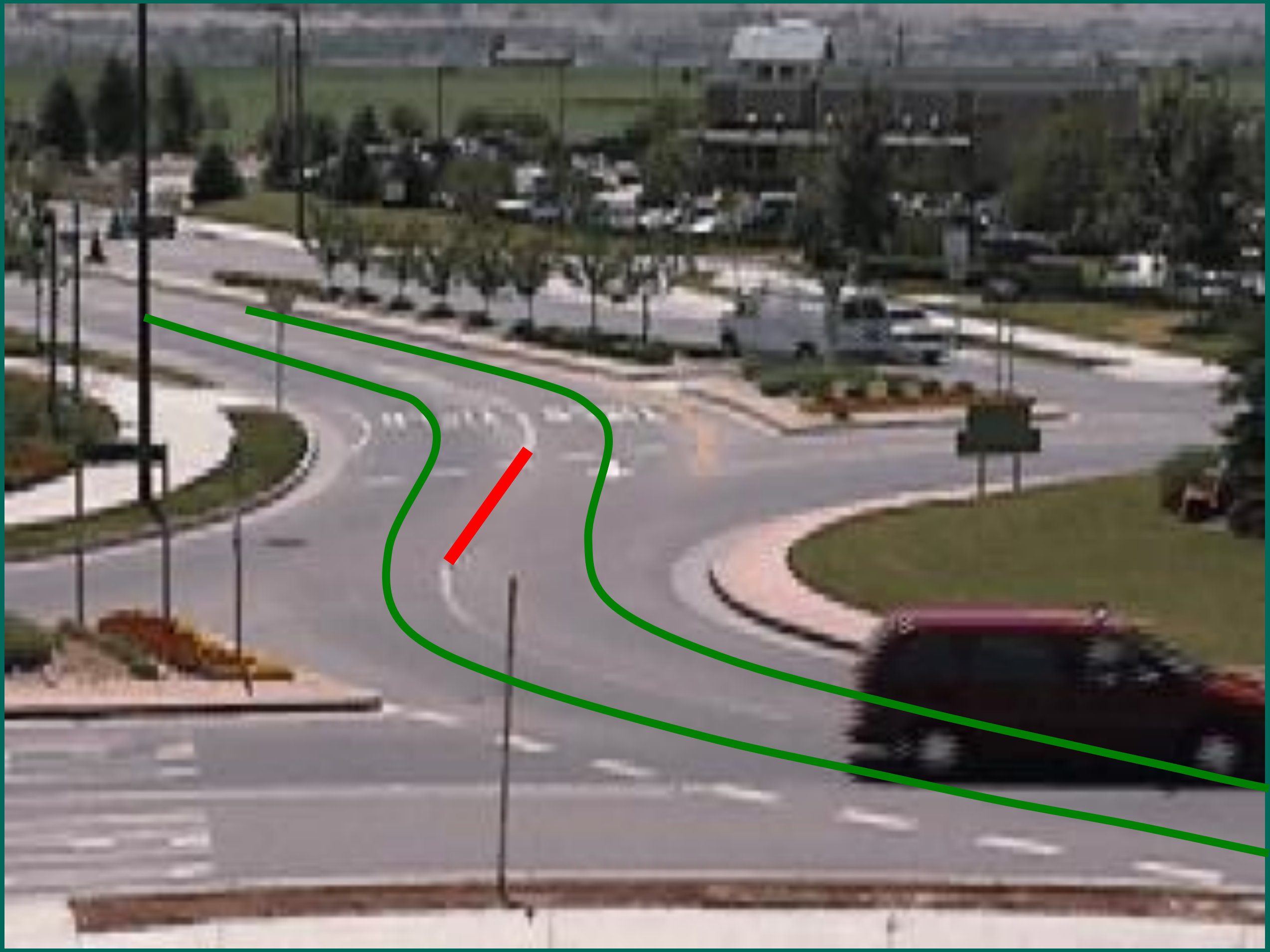
Poor Deflection + Entry Path Overlap



Unnatural Entry Paths Owing to Geometry

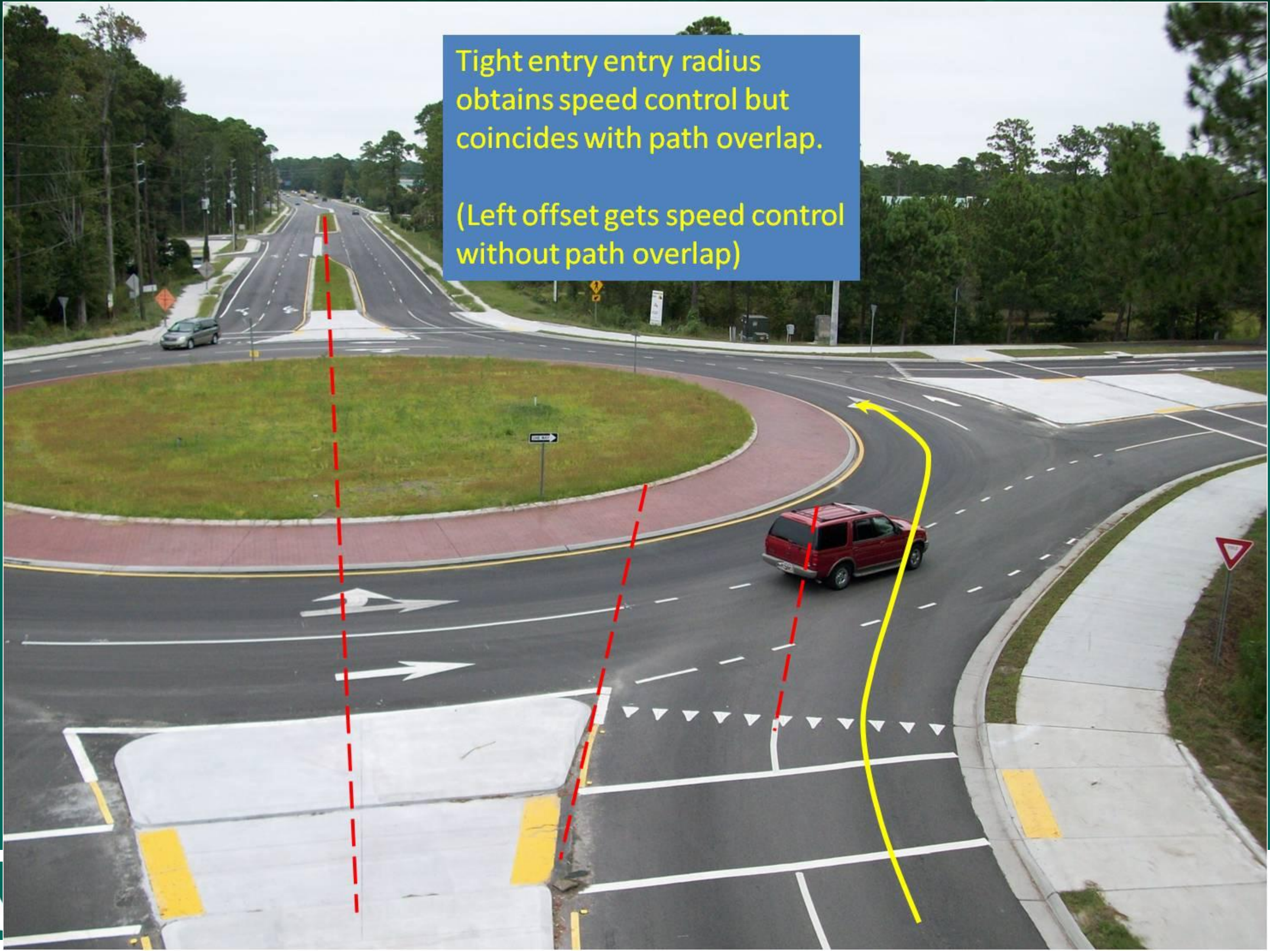
Unnatural Entry Paths Owing to Geometry

Good Entry Path Design

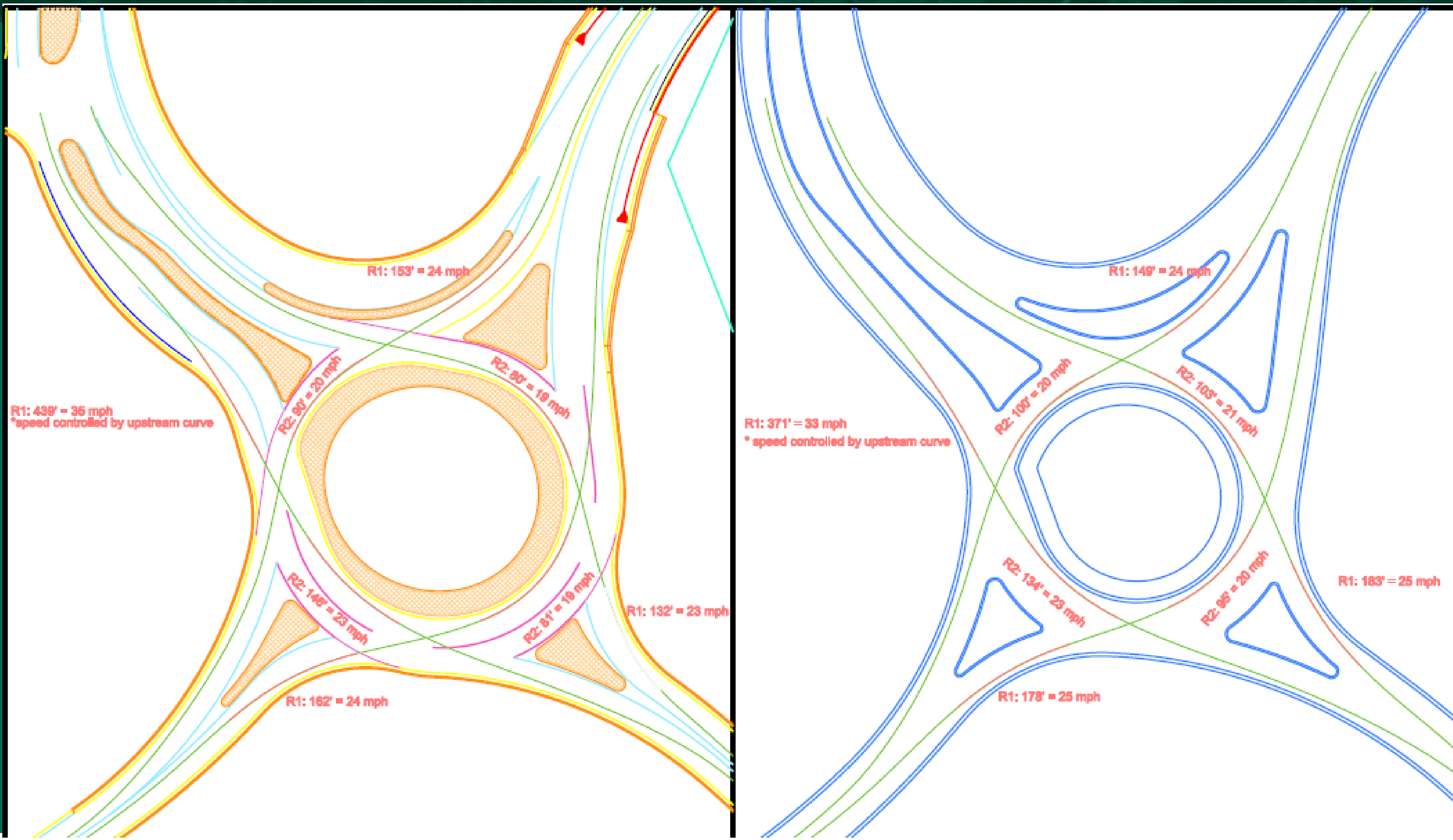


Exit Path Overlap

Radial vs. Offset Left Design



Compliance but Poor Composition



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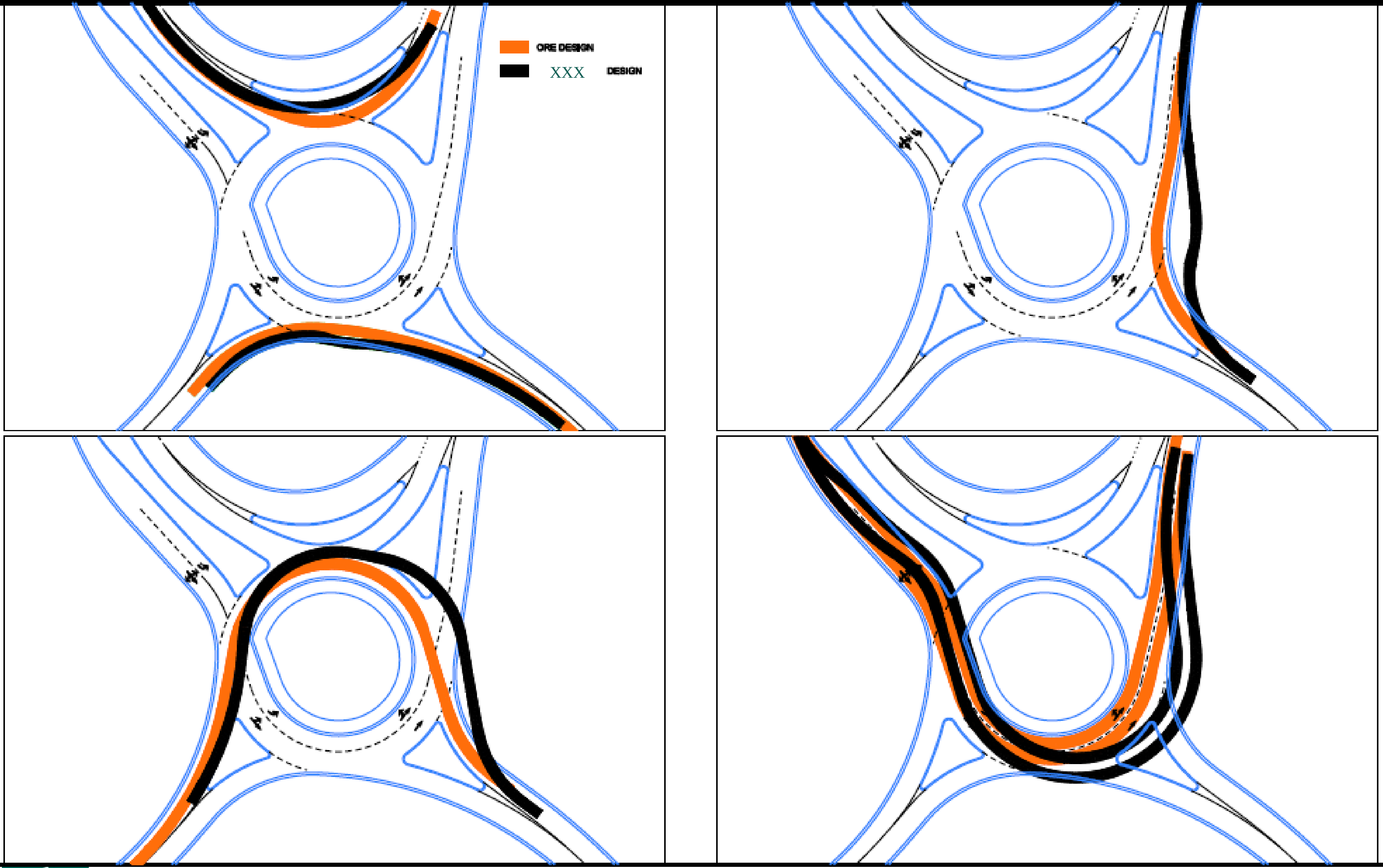
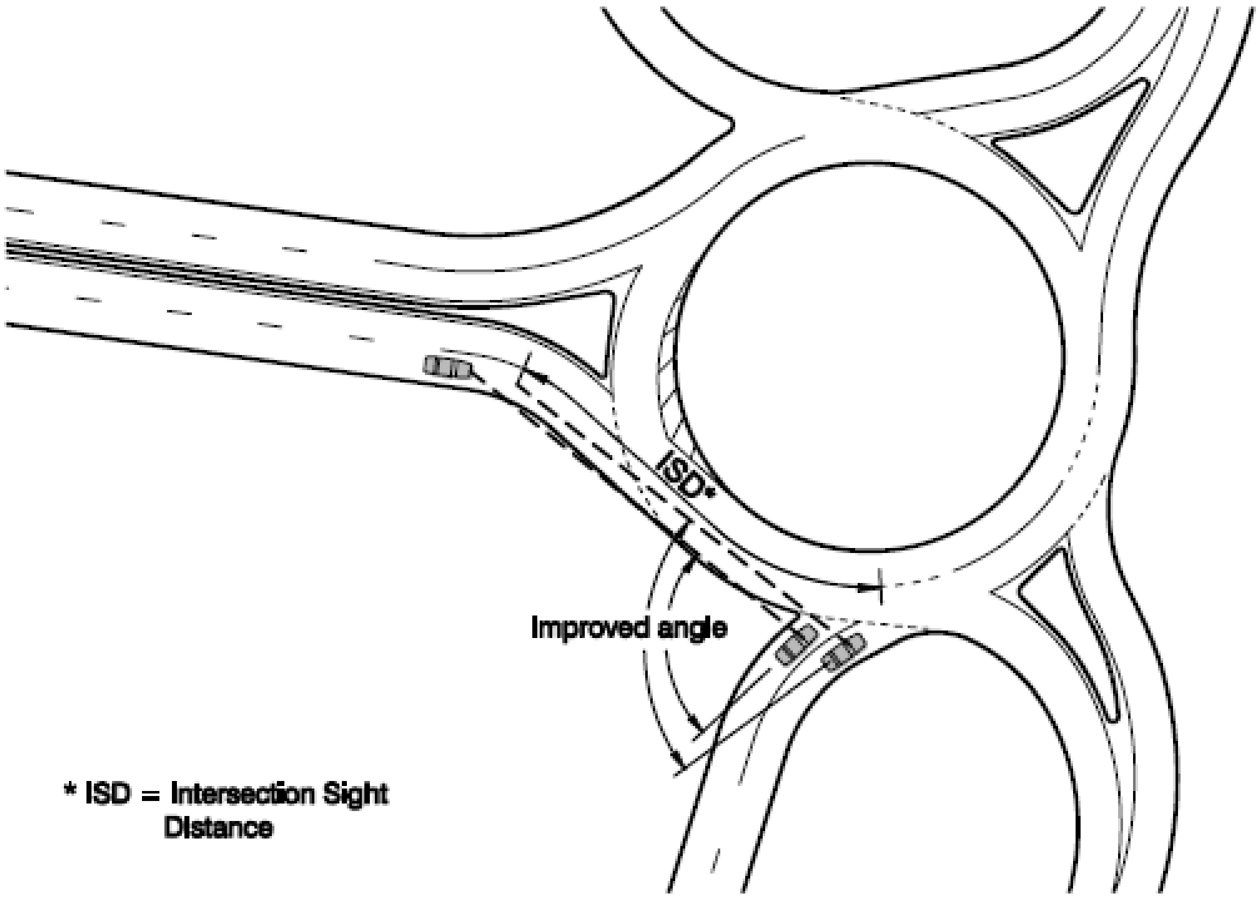


Angles of Visibility



Source: California Department of Transportation (1)

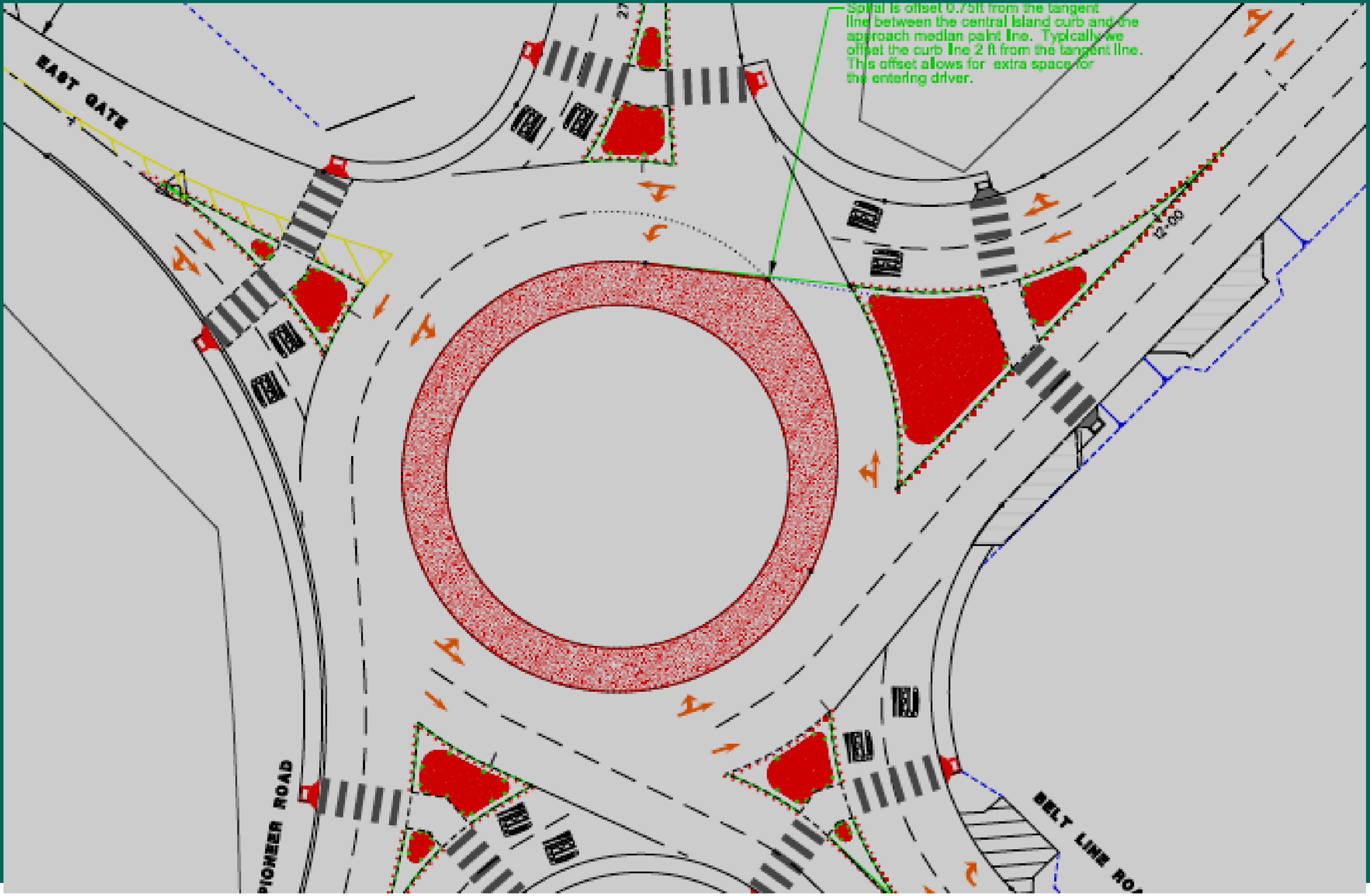
FHWA Roundabout Guide

Safety Issue #3: Traffic Information System

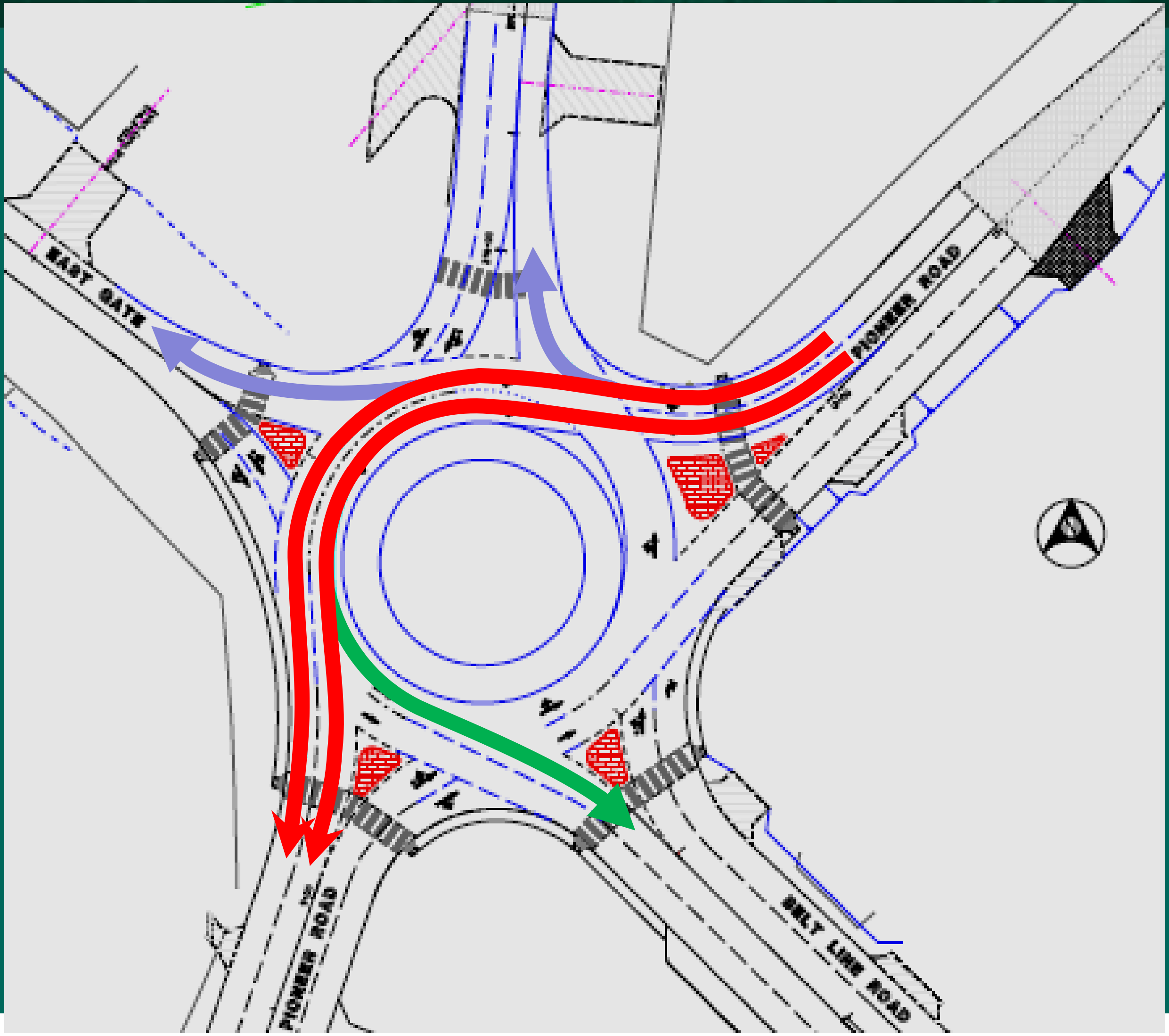
Incorrect Design Consequences:

- Incorrect lane choice – exit crashes (sideswipe)
- Sudden lane changes
- Weaving in the circle
- Improper left turns
- Navigational and way-finding errors

Coordination of Geometry and Lane Designation



Lane Choice Before Entry

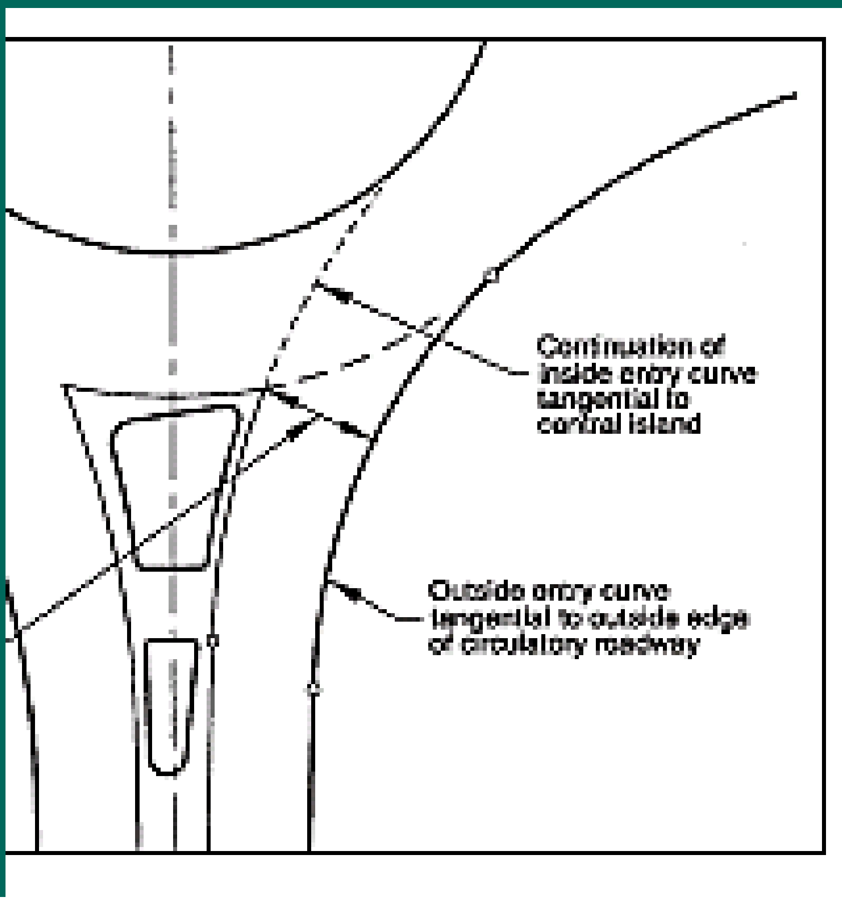


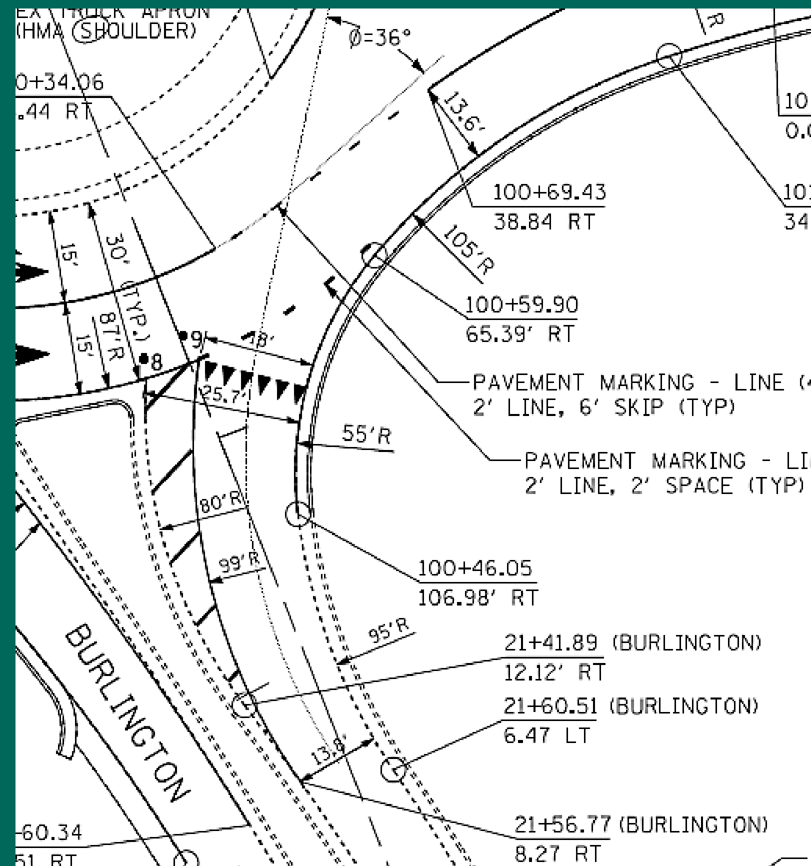
Lane Choice is Essential

Overhead Lane Designation Signs

Balanced designs require consideration for trucks

A WB-65 may require an 20 to 23 foot wide entry path

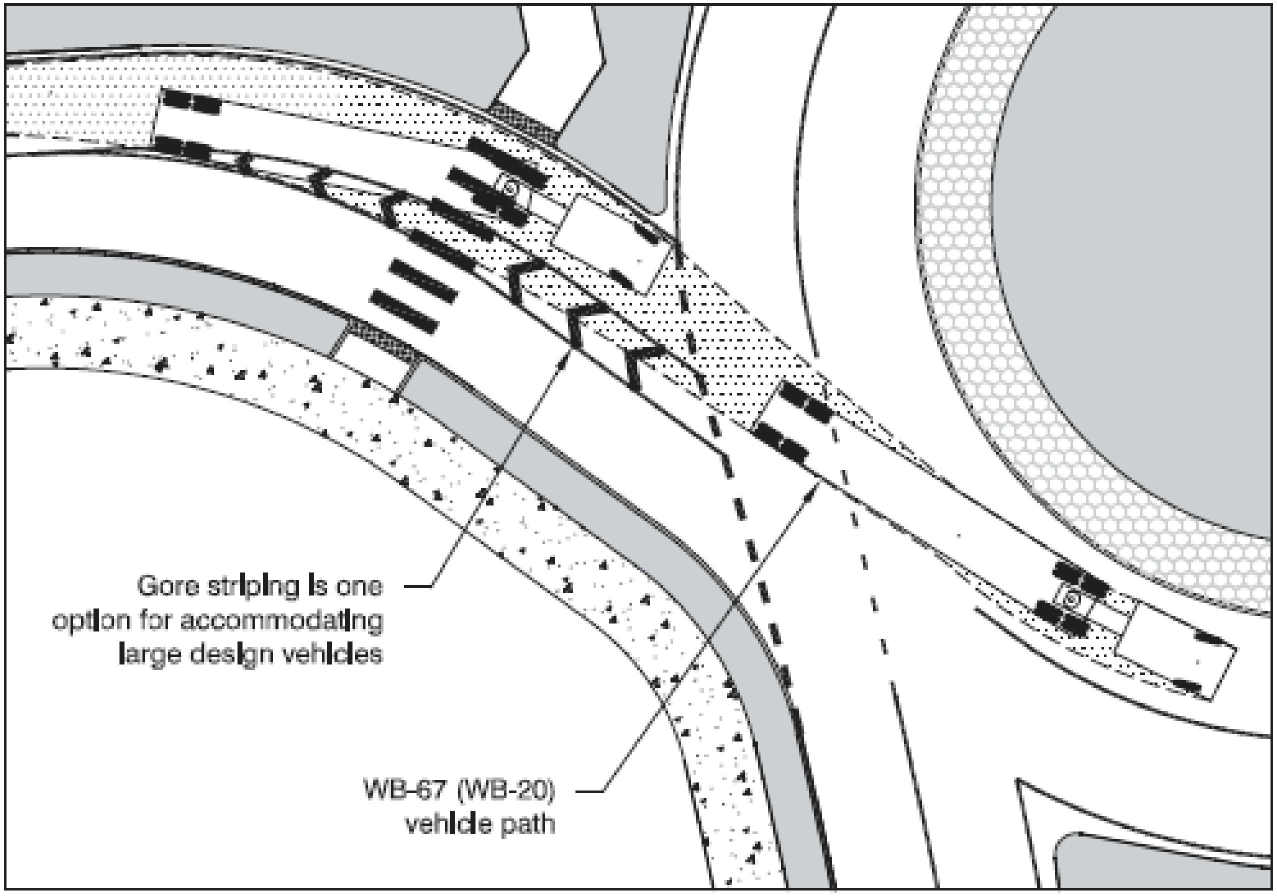




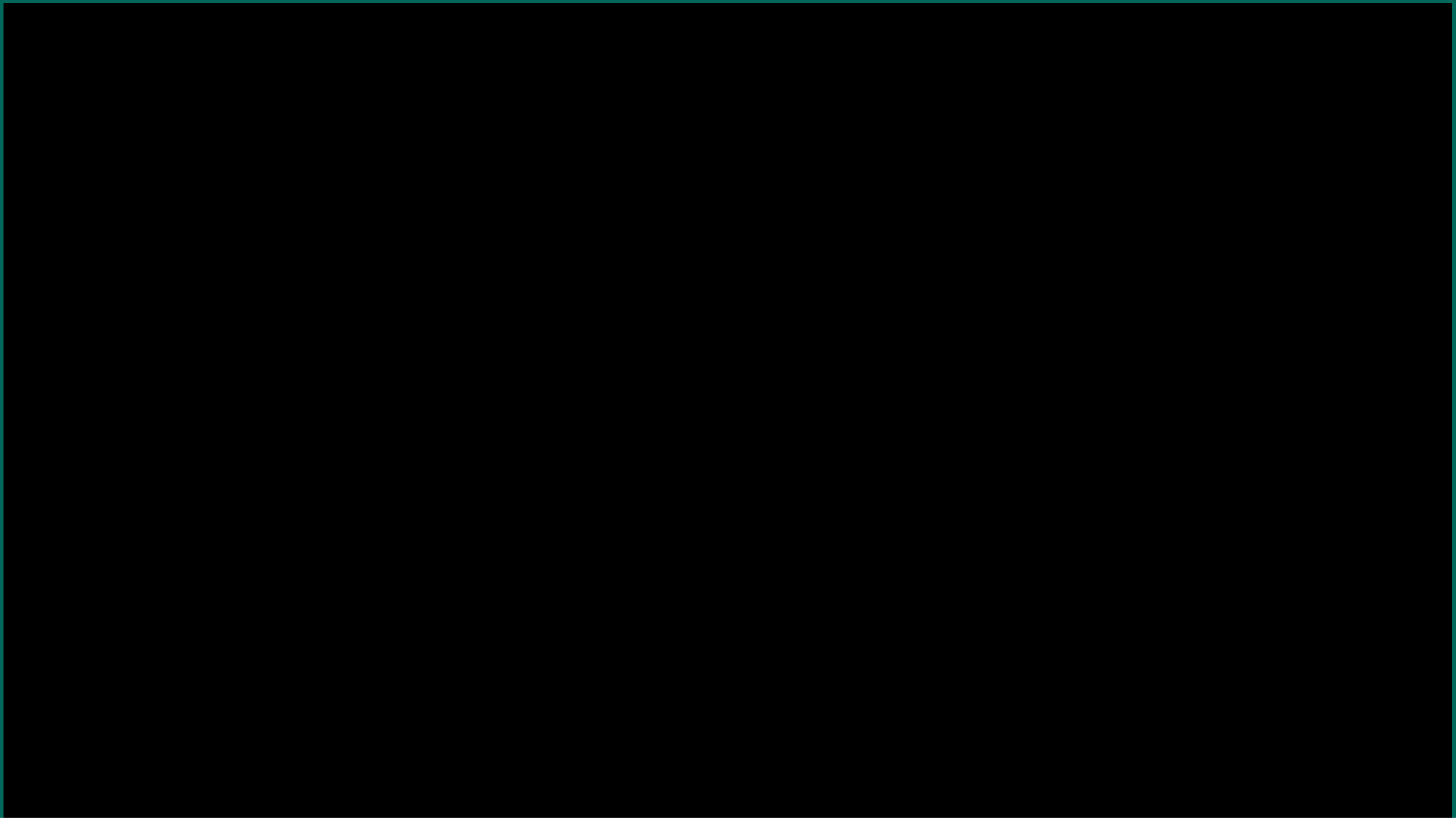
Each Site has a Different User Mix

- Freeways have more and larger trucks
  - Sometimes 30% trucks, rare pedestrians.
- Arterials mix fewer trucks
  - 3-15% and more frequent pedestrians
- Collectors: few trucks
  - ~ 1% or less depending on land use classification
- Local streets: cars, peds, school buses
- Isolated sites can have special user classes

A Trend Toward Wider Entries

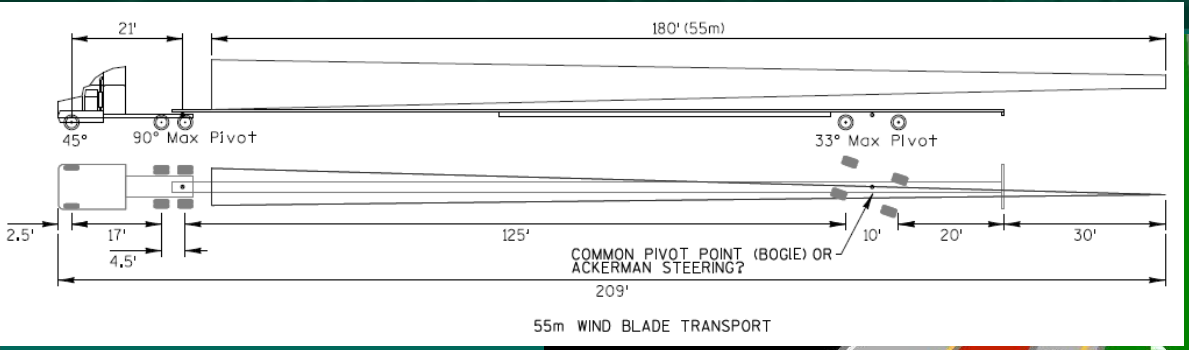


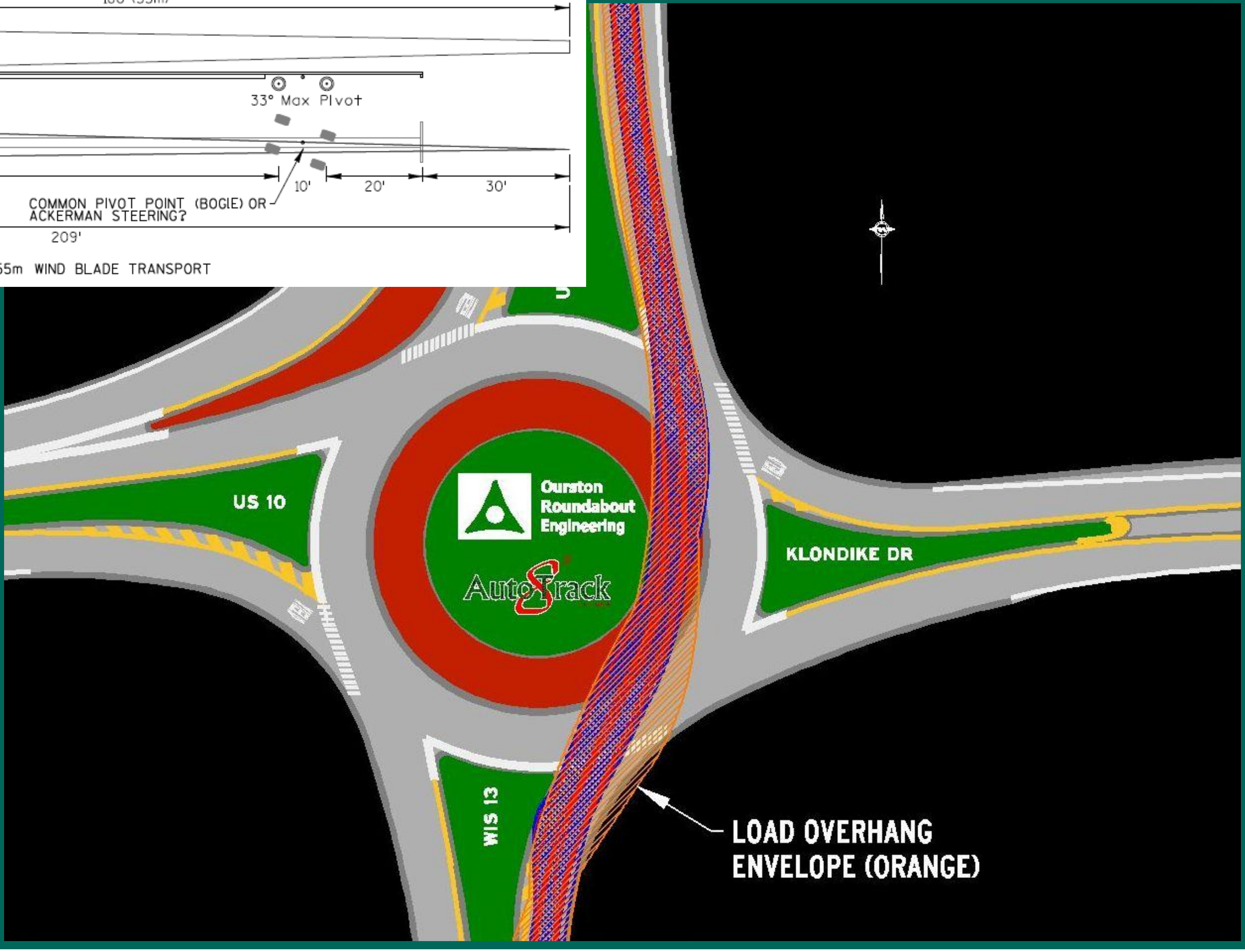
Source: New York State Department of Transportation (*11*)



Design Vehicle = WB-65?

Load Envelope Diagram





Grades

- Relatively flat circle desired (minor grade for drainage)
- Desirable profile through the circle is ≤ 4%

Photo source: Mark Doctor Brighton, CO

Visualize and extract the profiles before you build…

What do these all have in common?

- A poor understanding of the principles of safe roundabout operation
- The basic elements exist, but composition was overlooked
- Changes would not be costly
- Each will require a holistic approach to integrate the geometry with the project context

Ourston
Roundabout
Engineering

Balanced Design

- Roundabout operation is holistic – design should reflect this
- Balance competing needs of:
  - Achieving capacity
  - Providing space for trucks
  - Slowing speeds
  - Accommodating pedestrians

✓***ITERATIVE PROCESS!***

Balanced Design

- Design is a top down process
  - General first → specifics second

- Two parts to design

1. Problem solving – *<u>Strategic</u>* – What to do
2. Details – *<u>Tactical</u>* – Doing it

> Complexity = > Strategy

Safety Issue #1
Inadequate Entry Path Curvature (EPC)

SOLUTIONS:

- Adjust ICD size
- Adjust entry radius
- Offset entry alignment
- Apply EPC based on traffic flows – (ACCIDENT CHANGE IS A NET EFFECT)

Safety Issue #2:
Entry / Exit Path Overlap

RESULTS:

- Unnatural vehicle paths
- Sideswipe or rear-end entry-entry or exiting crashes (lane change)

Safety Issue #2: Entry/Exit Path Overlap

SOLUTIONS:

- Increasing exit radii
- Realigning entry
- Modify entry angle (compound radii and tangential entry/exit)
- Road markings (exit striping)

Geometric Parameters Affecting Safety:

- Entry Path Curvature
- Entry Width
- Approach lane(s) width
- Angle between arms
- Inscribed Circle Diameter/Central Island Diameter

- (U.K. Research TRL Report LR 1120)

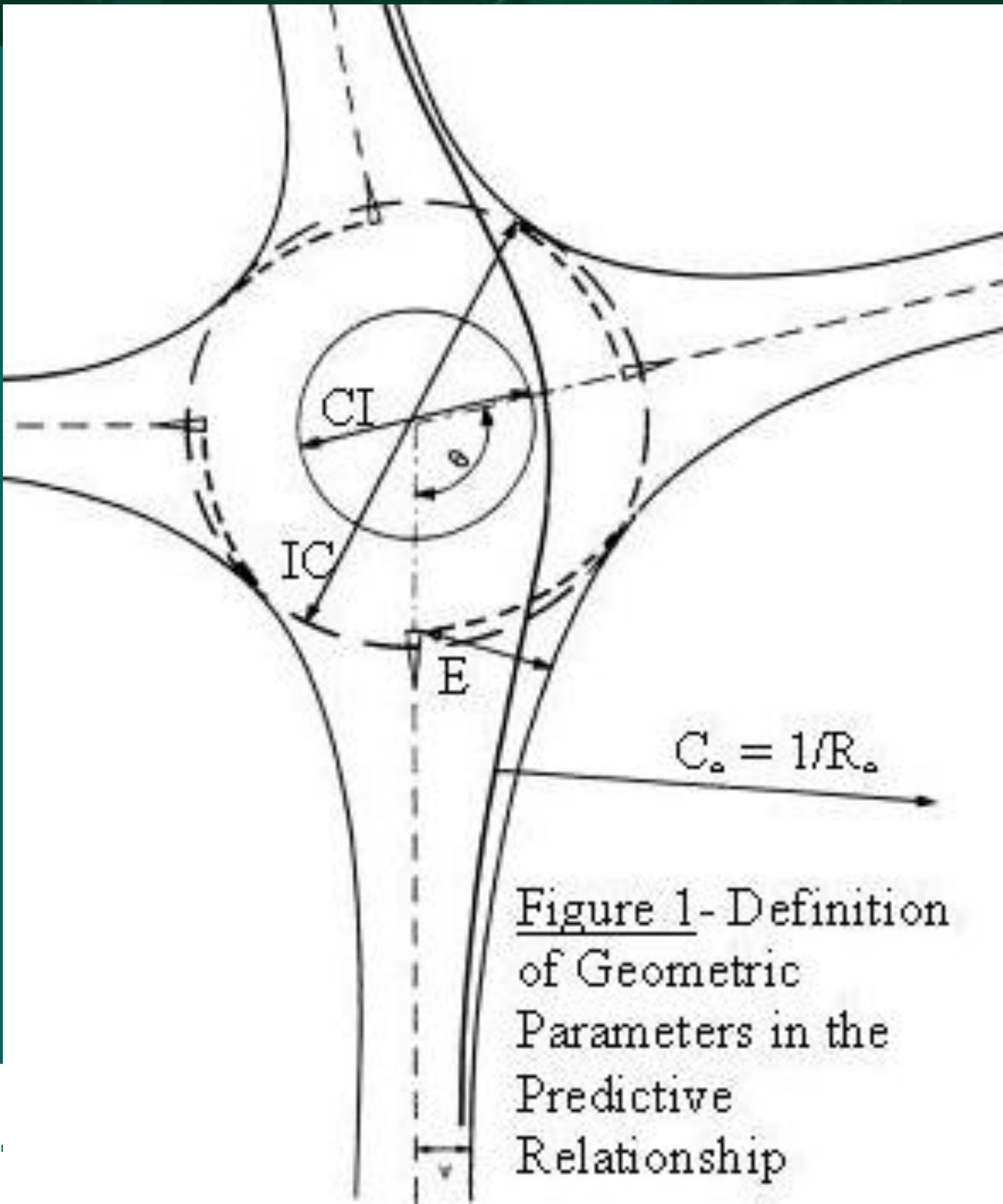


Figure 1 - Definition of Geometric Parameters in the Predictive Relationship

Performance Based Design

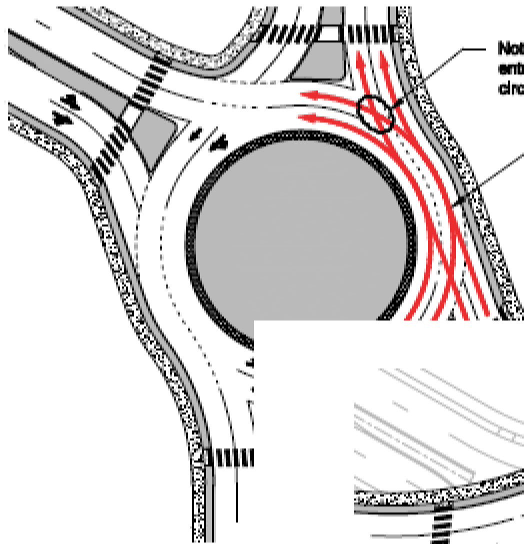
- We tend to try to create templates based on right-of-way or road classification
- Retrofits are not addressed in most standards
- Standard drawings don't address anomalies and unusual conditions – only principles can
- Producing an optimized design, requires effective application of operating principals (prior to designing)

Sign Clutter

(information overload)

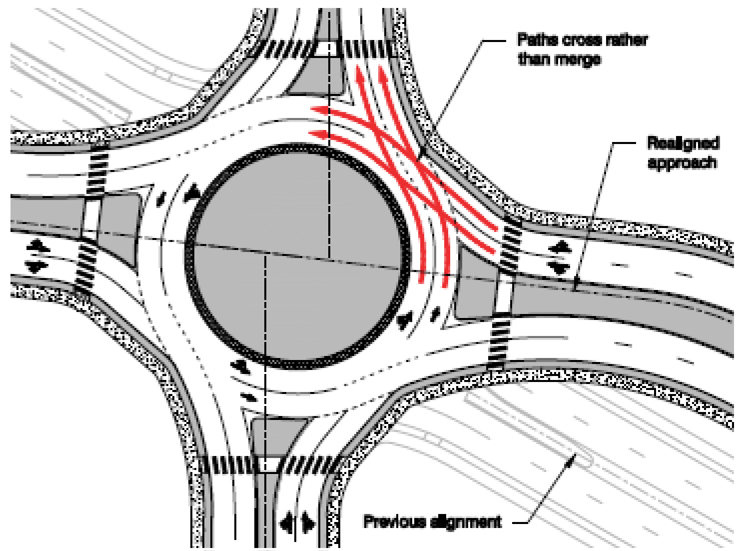
Spot the flaws…

Exhibit 6-33
Exit–Circulating Conflict Caused by Large Separation between Legs



Source: California Departme

Exhibit 6-35
Realignment to Resolve Exit–Circulating Conflicts



Source: California Department of Transportation (1)

Sample Policy for Roundabout Consideration

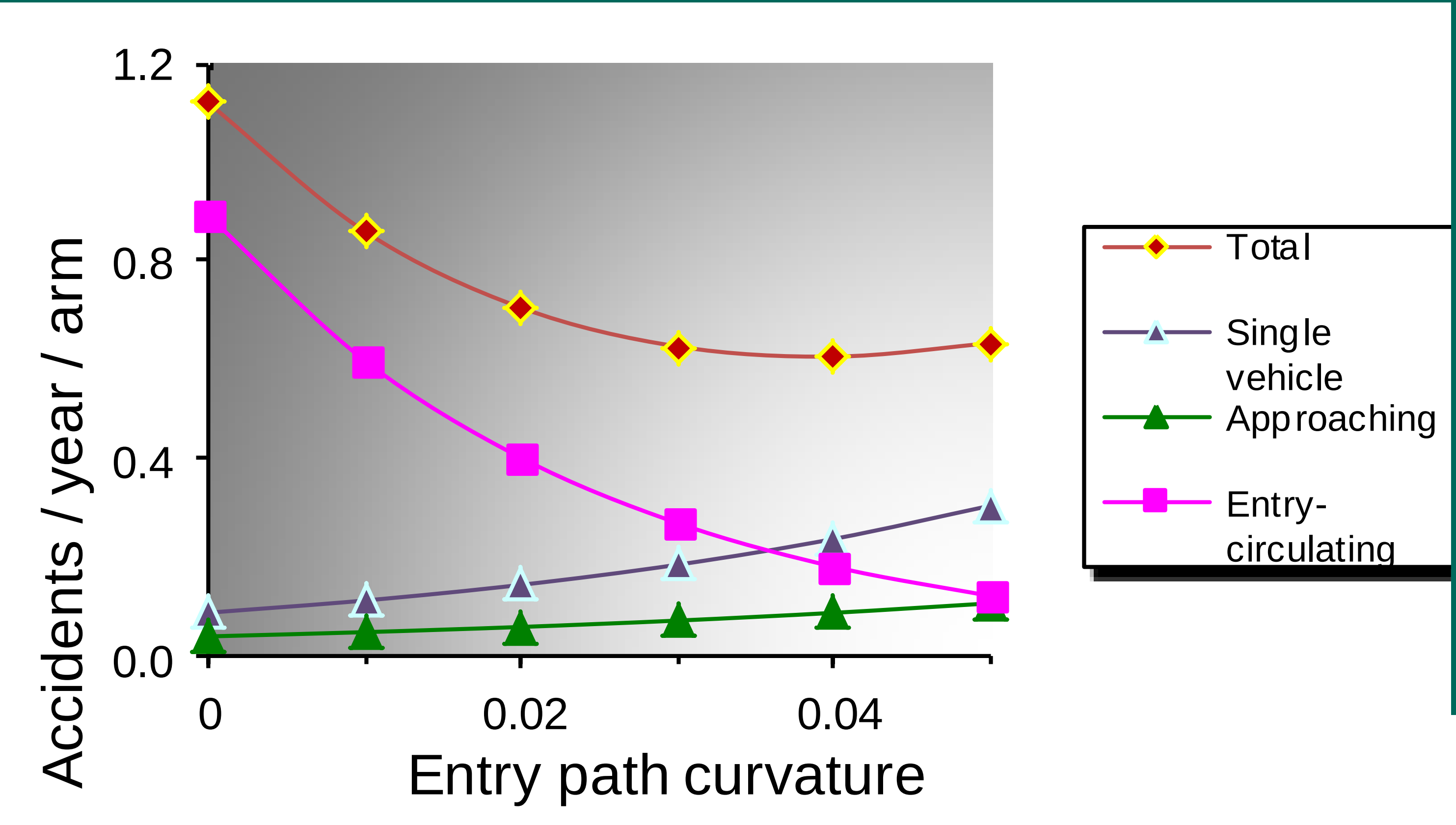
Specifically, a roundabout should be considered as an alternative in the following instances:

1. For any intersection that is being designed as new or is being reconstructed;
2. For all existing intersections that have been identified as needing major safety or operational improvements; and
3. For all intersections where a request for a traffic signal has been made.

Standard Roundabouts: Effect of Entry Path Curvature

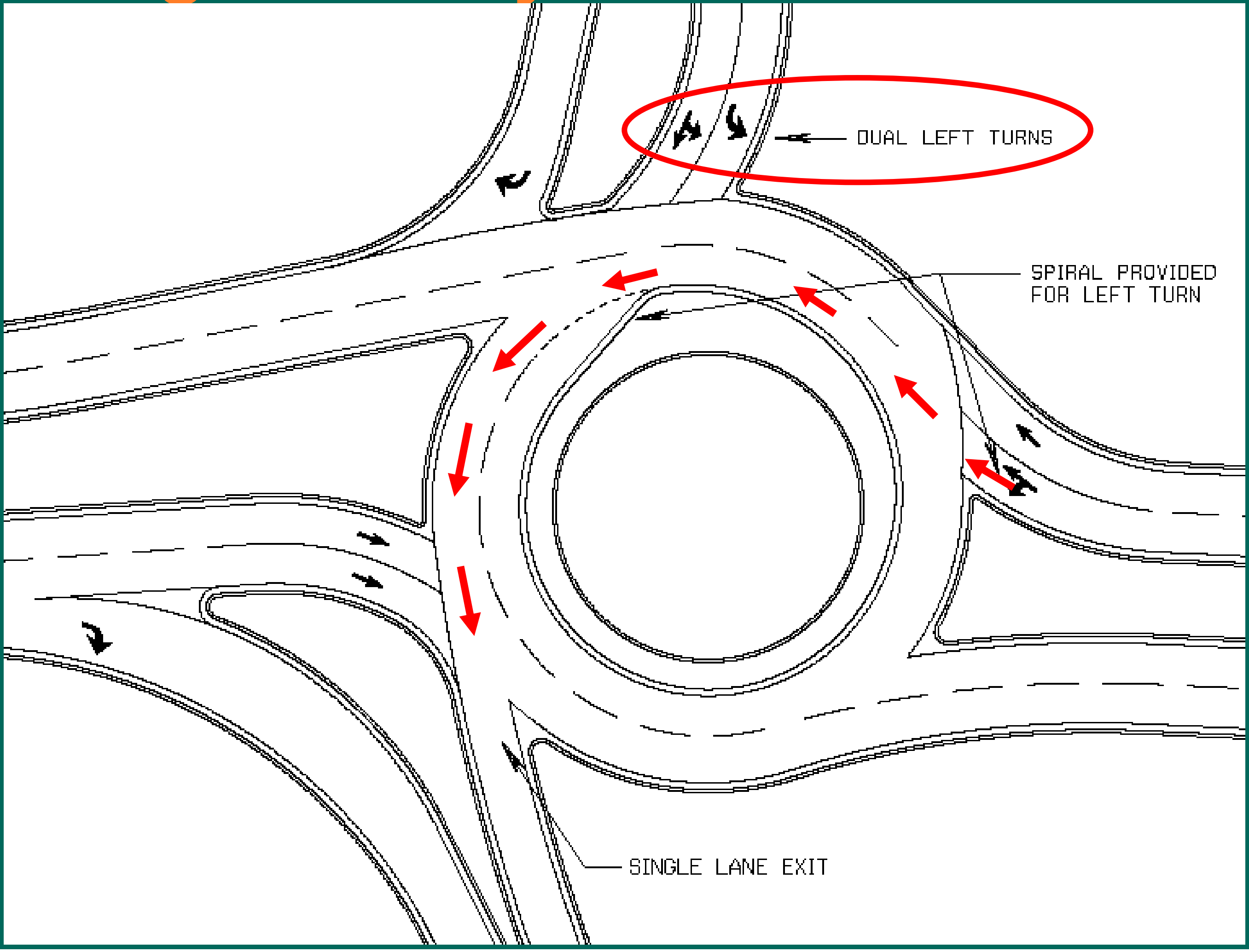
INCREASING entry path curvature…

- DECREASES entering-circulating accidents
- INCREASES approaching accidents
- INCREASES single vehicle accidents



Traffic affects markings/affects geometry

- Spiral markings set up for exclusive lanes and correct lane choice for exiting traffic



Spot the Strategic Flaws