Integrating Pedestrian and Bicyclist Safety in the Intersection Development and Design Process

June 2025

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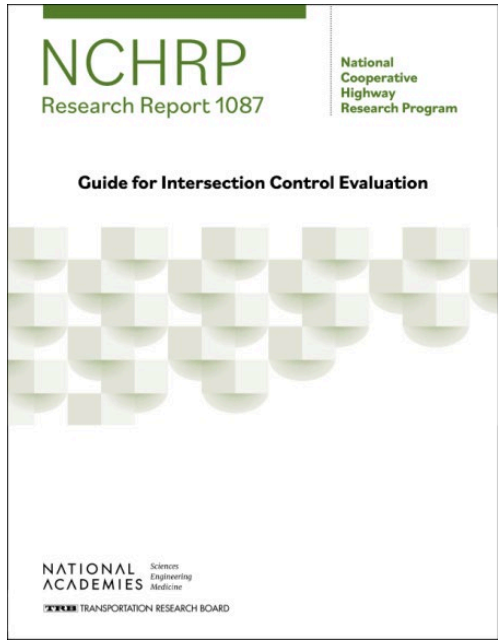
Overview

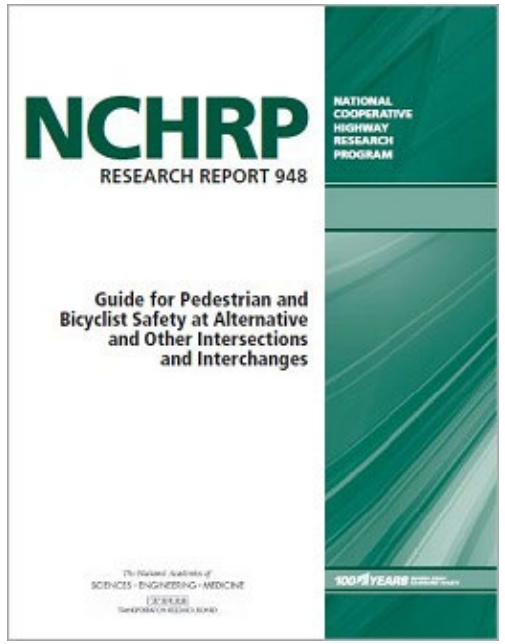


1

NCHRP Research Report 1087 – Guide for Intersection Control Evaluation (2024)

2

NCHRP Research Report 948 – Guide for Pedestrian and Bicyclist Safety at Alternative and Other Intersections and Interchanges (2020)



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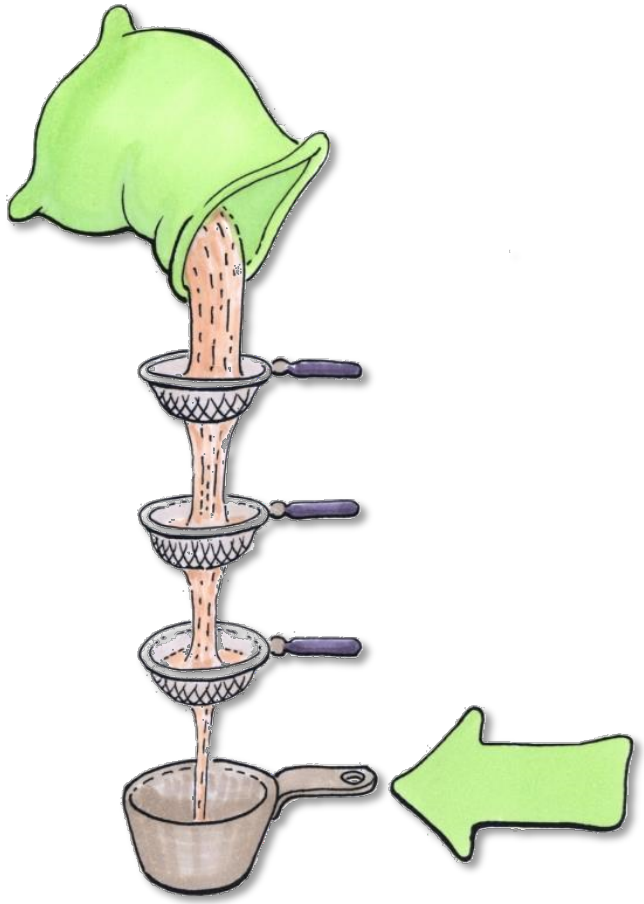
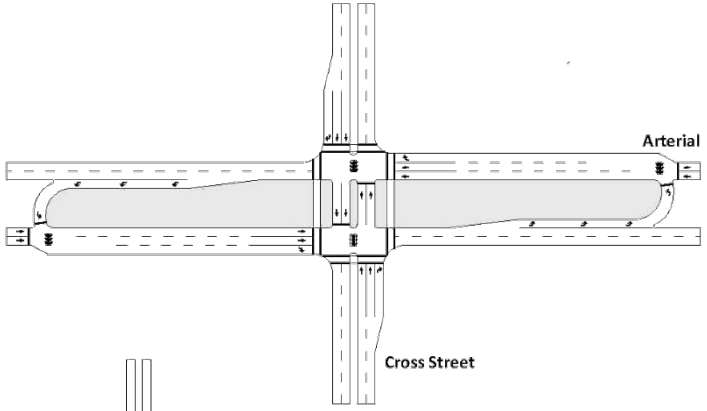
WOOD DUCK COVE
WOODS LN
NORMAN ISLAND DR (SR 2145)
COMMUNITY IN CHRIST LUTHERAN CHURCH
END R-5721B /BEGIN U-5765
-L_ALT1- STA. 412+73.76
MARINER COVE DR
FUTURE TIP PROJECT R-2555B
REGENCY PARK DR
HARRIS TEETER
W CATAWBA AVE (SR 5544)
LAKE NORMAN BAPTIST CHURCH
-Y27-
-Y28-
-Y29-
-Y30-
-Y31-
-Y32-
-L ALT1-
NC 73
SR 5544
WEST CATAWBA AVE
2016 ADT
2040 ADT
NUMBER OF VEHICLES PER DAY IN 100s

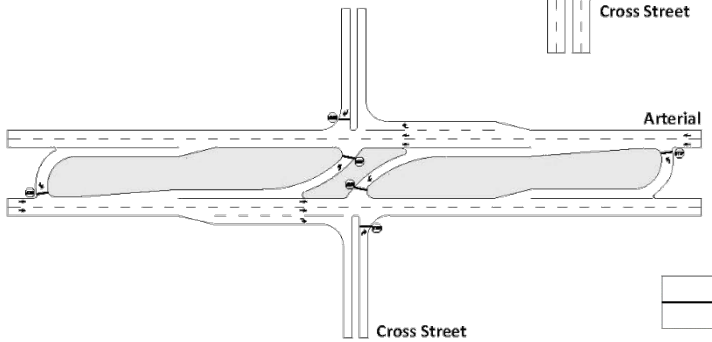
What is ICE?

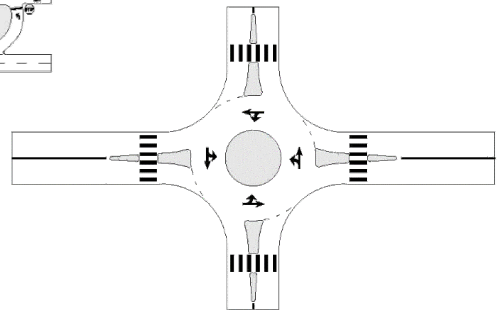
- A **process** that provides the framework, steps, tools, and decision-support for assessing trade-offs between different forms of intersections, as well as control types
- In many states, ICE is also a **policy** that establishes the general applicability and legal underpinnings for the process.

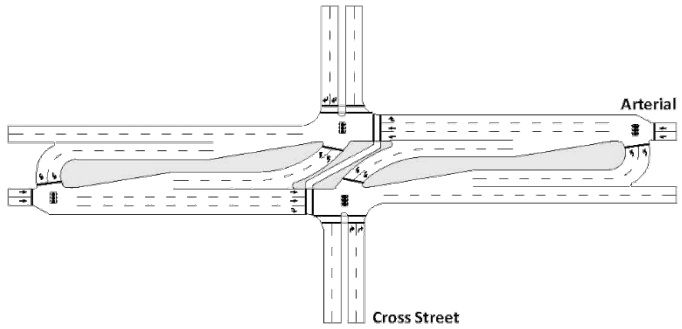


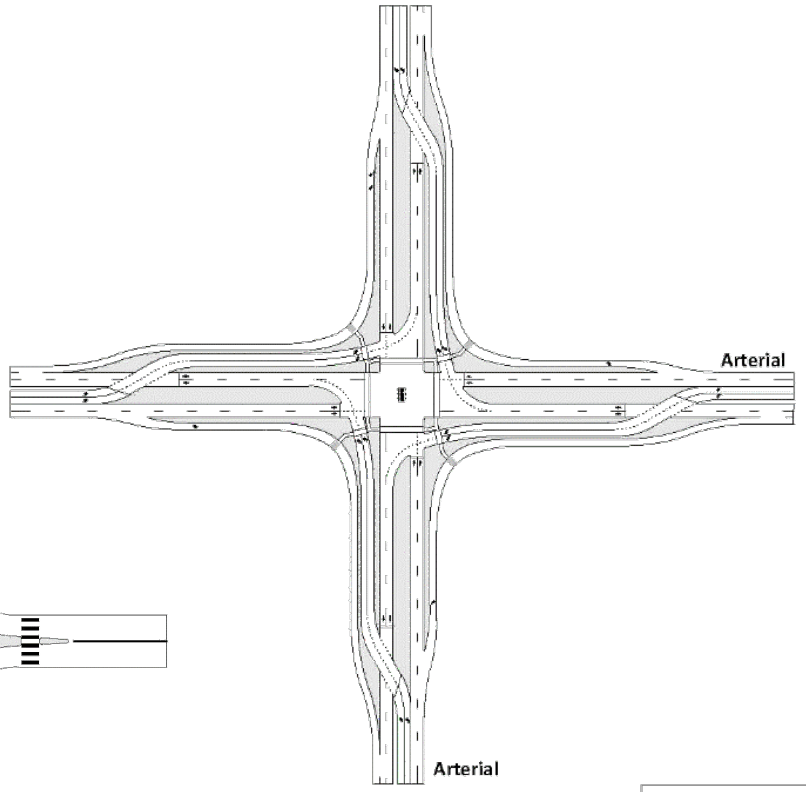
Intersection & Interchange Form and Control Evaluation – IIFCE?

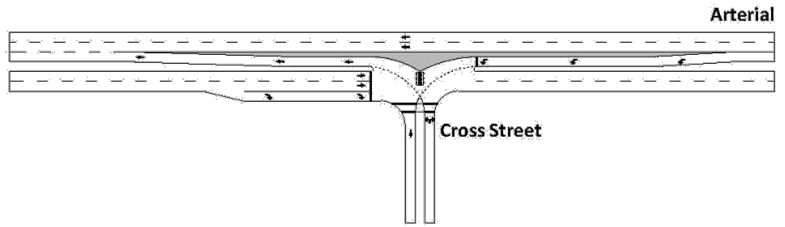


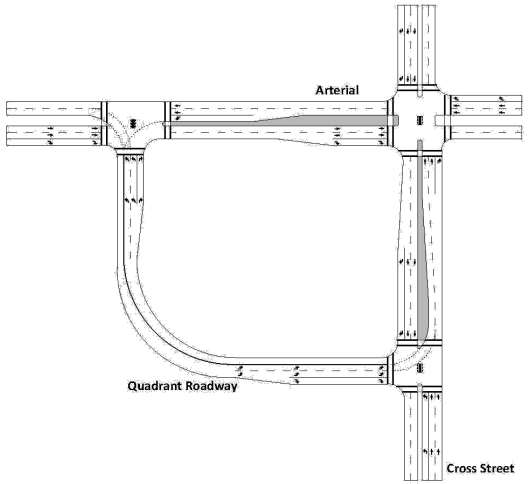


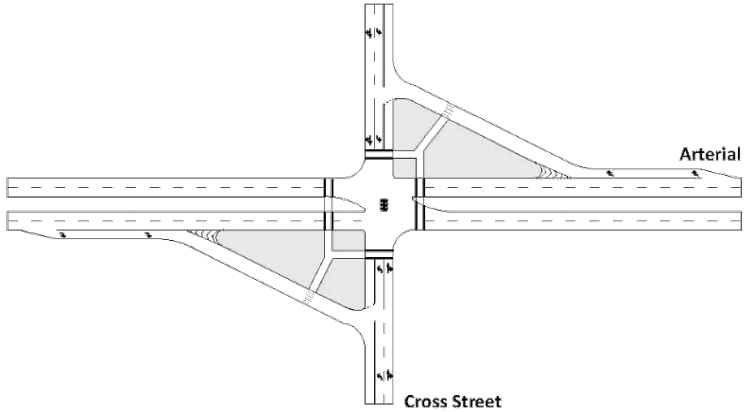












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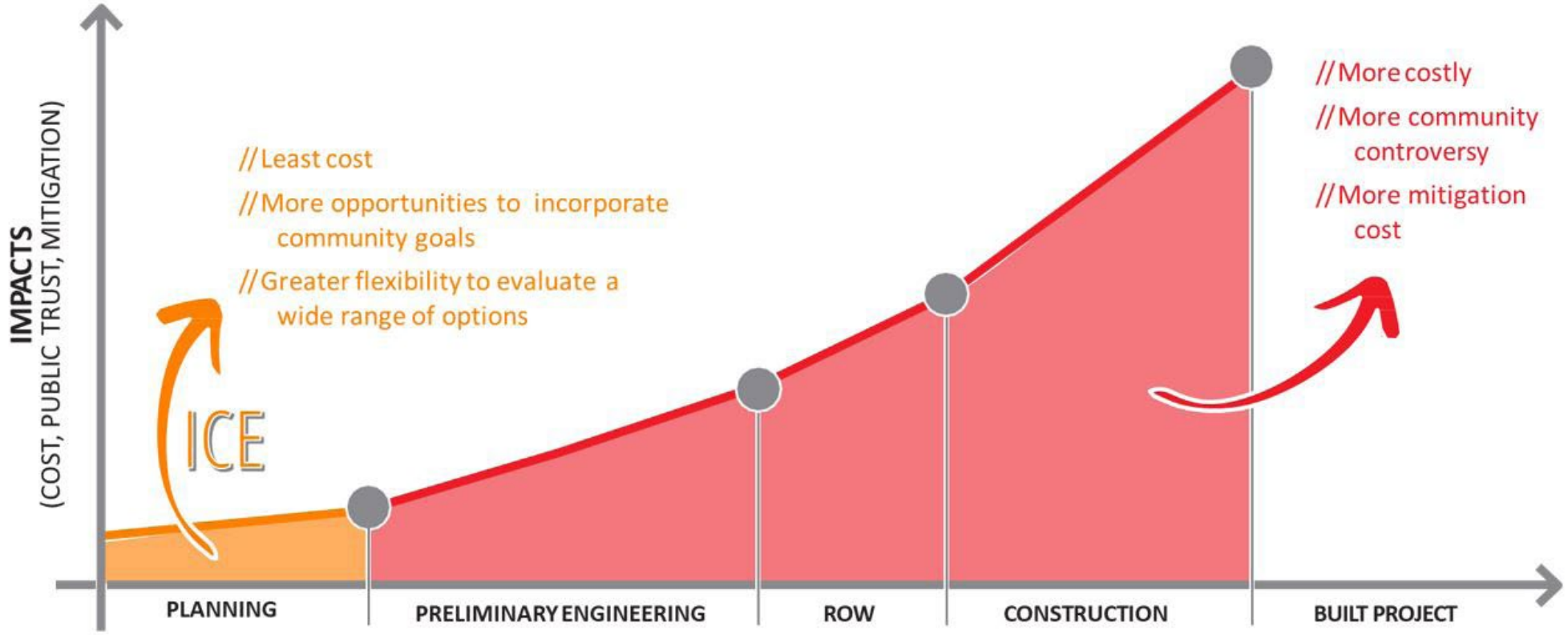
ICE in the Project Life Cycle



ICE offers agencies the opportunity to change decisions on intersection control and form early in the project life cycle during early planning stages, when project costs and public impacts are still low.

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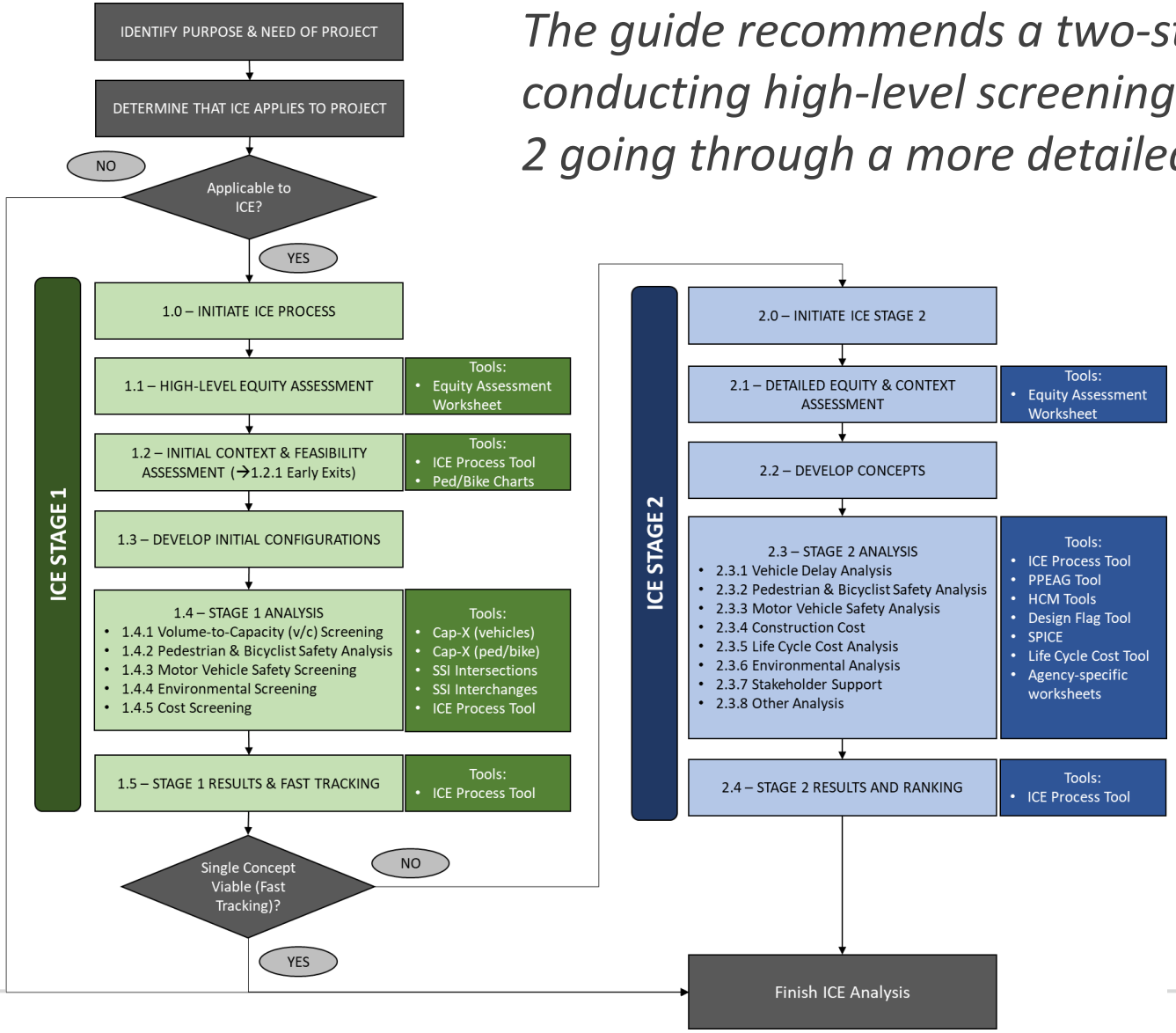
Typical ICE Process



The guide recommends a two-stage ICE process, with Stage 1 conducting high-level screening of (many) alternatives and Stage 2 going through a more detailed assessment of (few) alternatives

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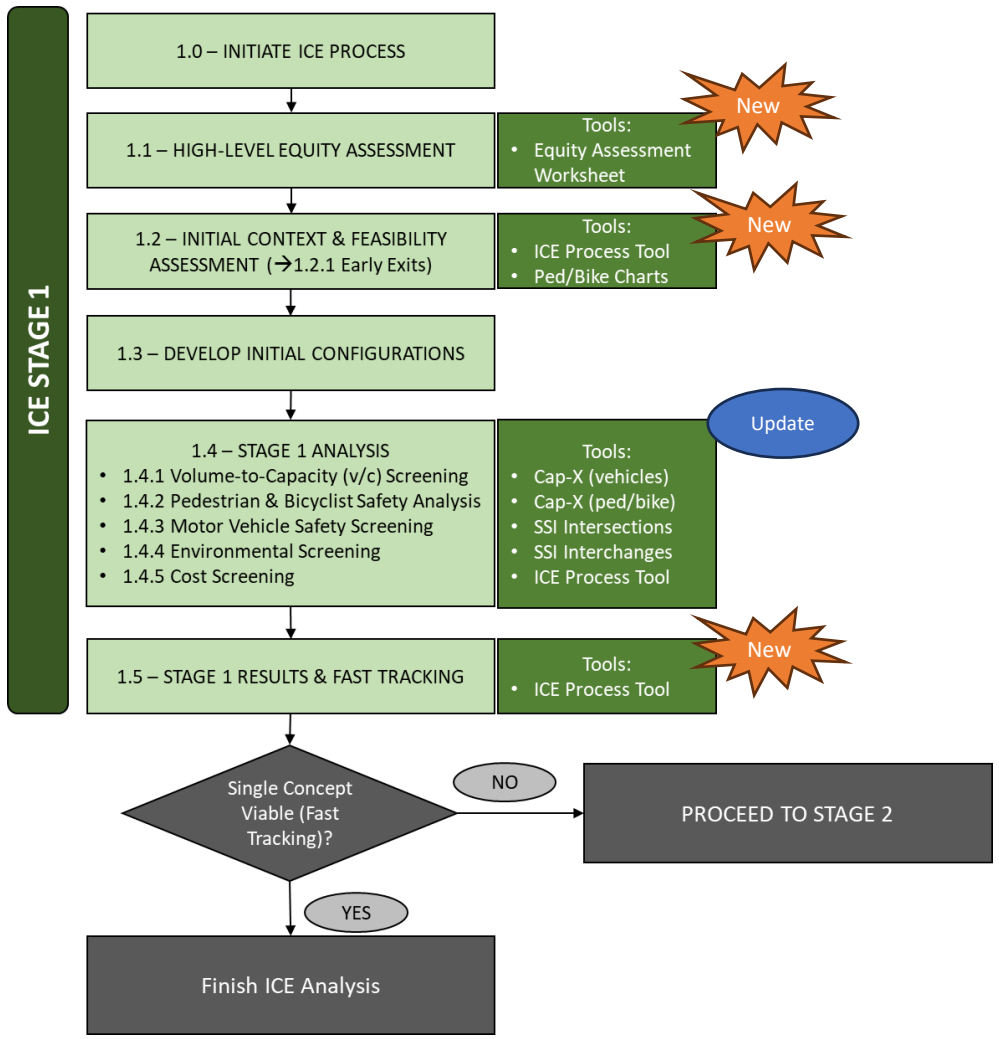
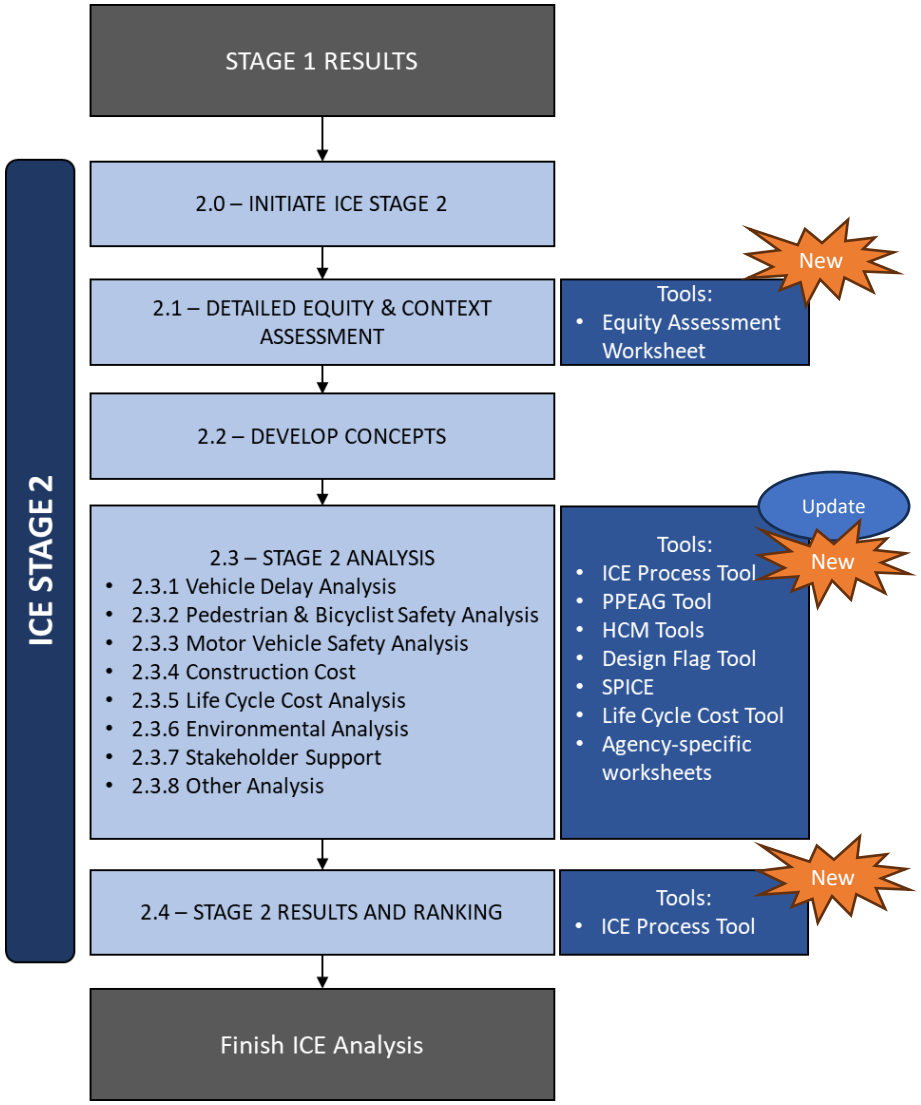
Components of ICE Stage 1



- *Integrate high-level context screening*
- *Incorporate 'early exits' of alternatives not feasible given project context*
- *Parallel assessment (NOT sequential filtering) of metrics*
  - *V/C screening*
  - *Multimodal safety assessment*
  - *Vehicular safety screening*
  - *Environmental screening*
  - *Cost screening*
- *Allow for 'fast tracking' of preferred alternative after Stage 1*

Components of ICE Stage 2



- *Integrate more detailed context screening*
- *Parallel assessment (NOT sequential filtering) of metrics*
  - *Vehicle Delay*
  - *Pedestrian and Bicyclist Safety*
  - *Motor Vehicle Safety*
  - *Construction Cost*
  - *Life Cycle Cost*
  - *Environment Analysis*
  - *Stakeholder Support*
  - *Other Analysis*

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Tools to Support ICE

Spreadsheets tools (part of ICE Guide)

- New — ICE Process Tool
- Update — Capacity Analysis for Planning of Junctions (CAP-X) Tool
- New — Planning and Preliminary Engineering Applications Guide (PPEAG) ICE Tool
- New — Context Assessment Tool
- New — 20 Flags Calculator Tool
- Updated — Safe Systems for Intersections (SSI) Tools
- Updated — Safety Performance for Intersection Control Evaluation (SPICE) Tool
- Updated — Life-Cycle Cost Estimating Tool (LCCET)

Other Tools

- Agency-Level ICE Tools
  - PennDOT Web ICE Tool
  - VDOT VJuST Tool
- Safety Screening Tools
  - CrashKit™
- Operations Analysis Software
  - Synchro
  - HCS
  - VISSIM
  - VISTRO
  - Etc.

Example: SPICE Tool

- Safety Performance for Intersection Control Evaluation (SPICE)
- Originally developed by Kittelson for FHWA in 2018
- Uses the Safety Performance Functions (SPFs) in HSM Part C
- Updated for various state DOTs and for NCHRP ICE Guide

Safety Performance for Intersection Control Evaluation Tool

Results

Summary of crash prediction results for each alternative

Project Information

Project Name:	Sample	**Intersection Type**	At-Grade Intersections
Intersection:	Test Intersection	**Opening Year**	2018
Agency:	KAI	**Design Year**	2035
Project Reference:	NCHRP 17-98	**Facility Type**	On Urban and Suburban Arterial
City:	Wilmington	**Number of Legs**	4-leg
State:	NC		
Date:	3/1/2022		
Analyst:	BJS		

Crash Prediction Summary

Control Strategy	Crash Type	Opening Year	Design Year	Total Project Life Cycle	AADT Within Prediction Range?
1-lane Roundabout	Total	1.26	1.63	26.13	N/A
	Fatal & Injury	0.19	0.25	3.92	
2-lane Roundabout	Total	1.82	2.35	37.69	N/A
	Fatal & Injury	No SPF	No SPF	No SPF	
Minor Road Stop	Total	2.07	2.67	42.83	No
	Fatal & Injury	0.85	1.12	17.81	
Traffic Signal	Total	3.22	4.28	67.64	Yes
	Fatal & Injury	1.08	1.44	22.74	
Traffic Signal (Alt)	Total	3.72	4.94	78.23	Yes
	Fatal & Injury	1.25	1.66	26.26	
Displaced Left-Turn (DLT)	Total	2.83	3.76	59.52	N/A
	Fatal & Injury	0.95	1.27	20.01	
Median U-Turn (MUT)	Total	2.74	3.63	57.49	N/A
	Fatal & Injury	0.76	1.01	15.92	
Signalized RCUT	Total	2.74	3.63	57.49	N/A
	Fatal & Injury	0.84	1.12	17.74	
Unsignalized RCUT	Total	1.35	1.74	27.84	N/A
	Fatal & Injury	0.39	0.52	8.19	

Example: 20-Flag Tool

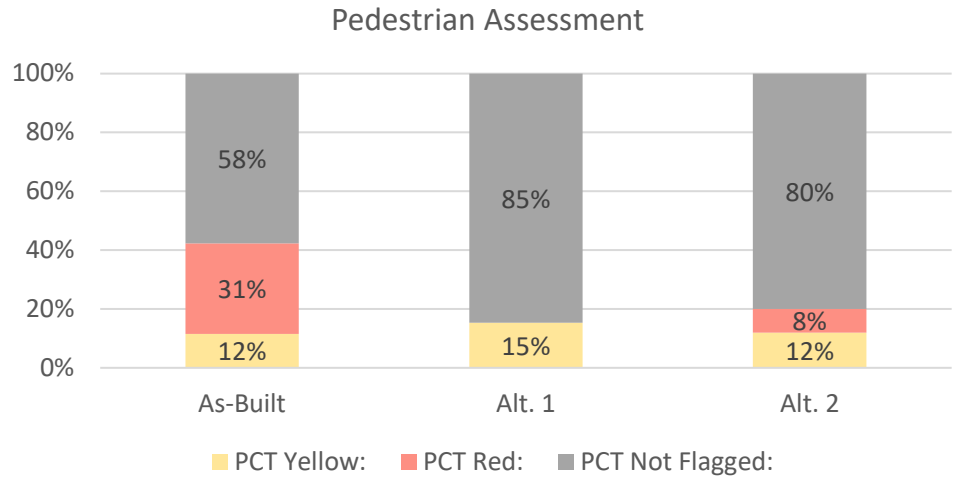
- Spreadsheet Tool to Implement the 20-Flag Method developed through NCHRP 948
- Updated for NCHRP 1087 for consistent look and formatting
- Used to track and summarize flag assessment

Scenario 1

Intersection Type: (REQUIRED FIELD)	Signal
Analysis Intersection:	

		Pedestrian Assessment				Bicycle Assessment											
Flag #	Flag	West	East	North	South	NBL	NBT	NBR	SBL	SBT	SBR	EBL	EBT	EBR	WBL	WBT	WBR
1	Motor Vehicle Right Turn	Red	Red	Red	Red												
2	Uncomfortable/ Tight Walking Environment																
3	Non-Intuitive Motor Vehicle Movement																
4	Crossing Yield or Uncontrolled Vehicle Paths	Red	Red	Red	Red												
5	Indirect Paths																
6	Executing Unusual Movements																
7	Multilane Crossing	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
8	Long Red Times	Red	Red	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Red	Red	Red	Red	Red	Red
9	Undefined Crossing at Intersections																
10	Motor Vehicle Left Turn	Red	Red	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Red	Red	Red	Red	Red	Red
11	Intersecting Driveways and Side Streets																
12	Sight Distance for Gap Acceptance																
13	Grade Change																
14	Riding in Mixed Traffic					Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
15	Bicycle Clearance Times																
16	Lane Change Across Motor Vehicle Lanes					Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
17	Channelized Lanes																
18	Turning Motorists Crossing Bicycle Path																
19	Riding Between Travel Lanes																
20	Off-Tracking Trucks in Multi-Lane Curves																
	Total Yellow Flags Movement	0	0	2	2	2	2	2	2	2	2	0	0	0	0	0	0
	Total Red Flags by Movement	5	5	3	3	3	3	3	3	3	3	5	5	5	5	5	5

	All	Pedestrian	Bicycle
Total Yellow Flags:	16	4	0
Total Red Flags:	64	16	24
Total No Flags:	0	0	0
Total N/A:	0	0	0
Total Possible:	136	52	84
Percent Yellow:	12%	8%	0%
Percent Red:	47%	31%	29%
Percent Not Flagged:	41%	62%	71%



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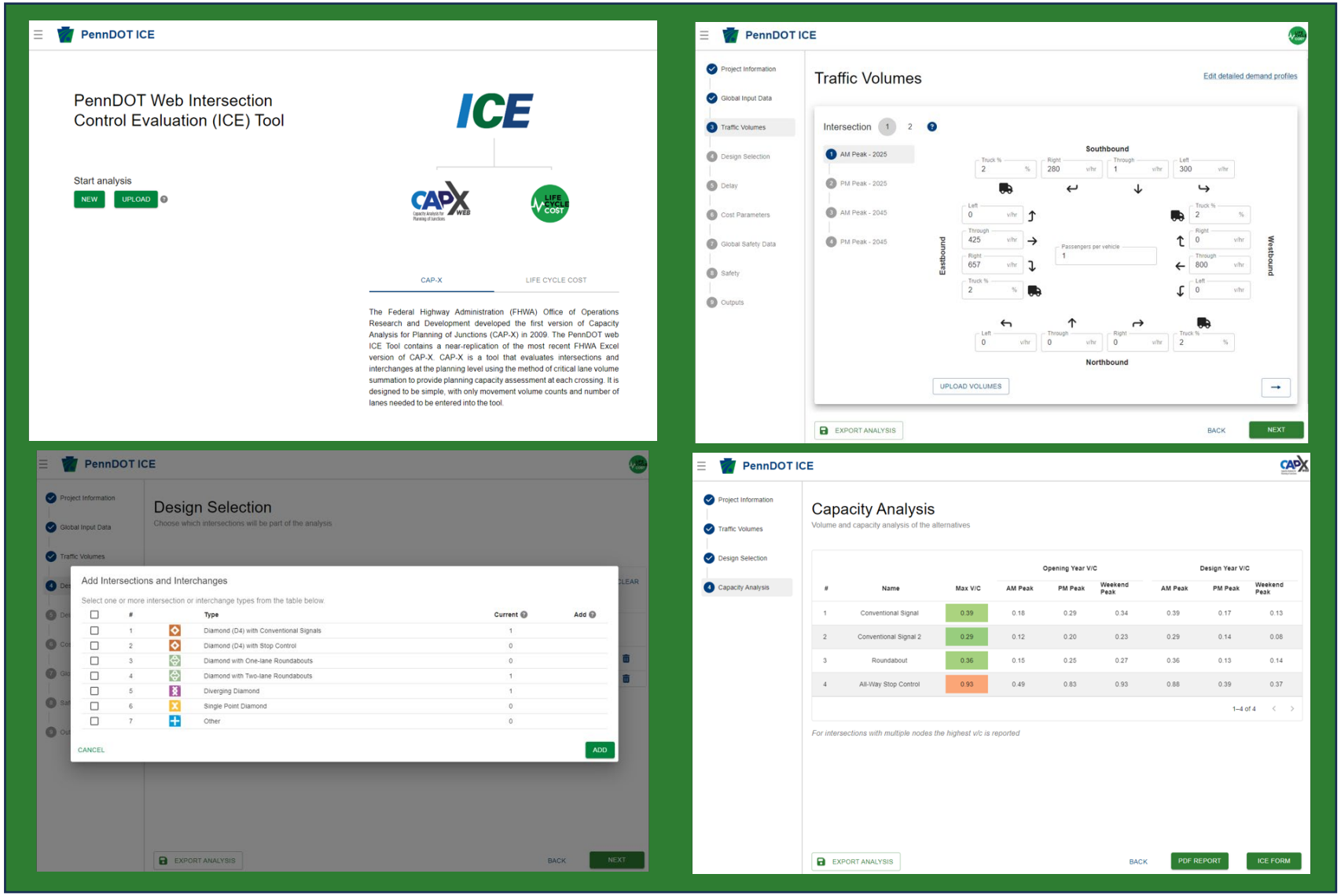
Web-Based Implementation: PennDOT ICE



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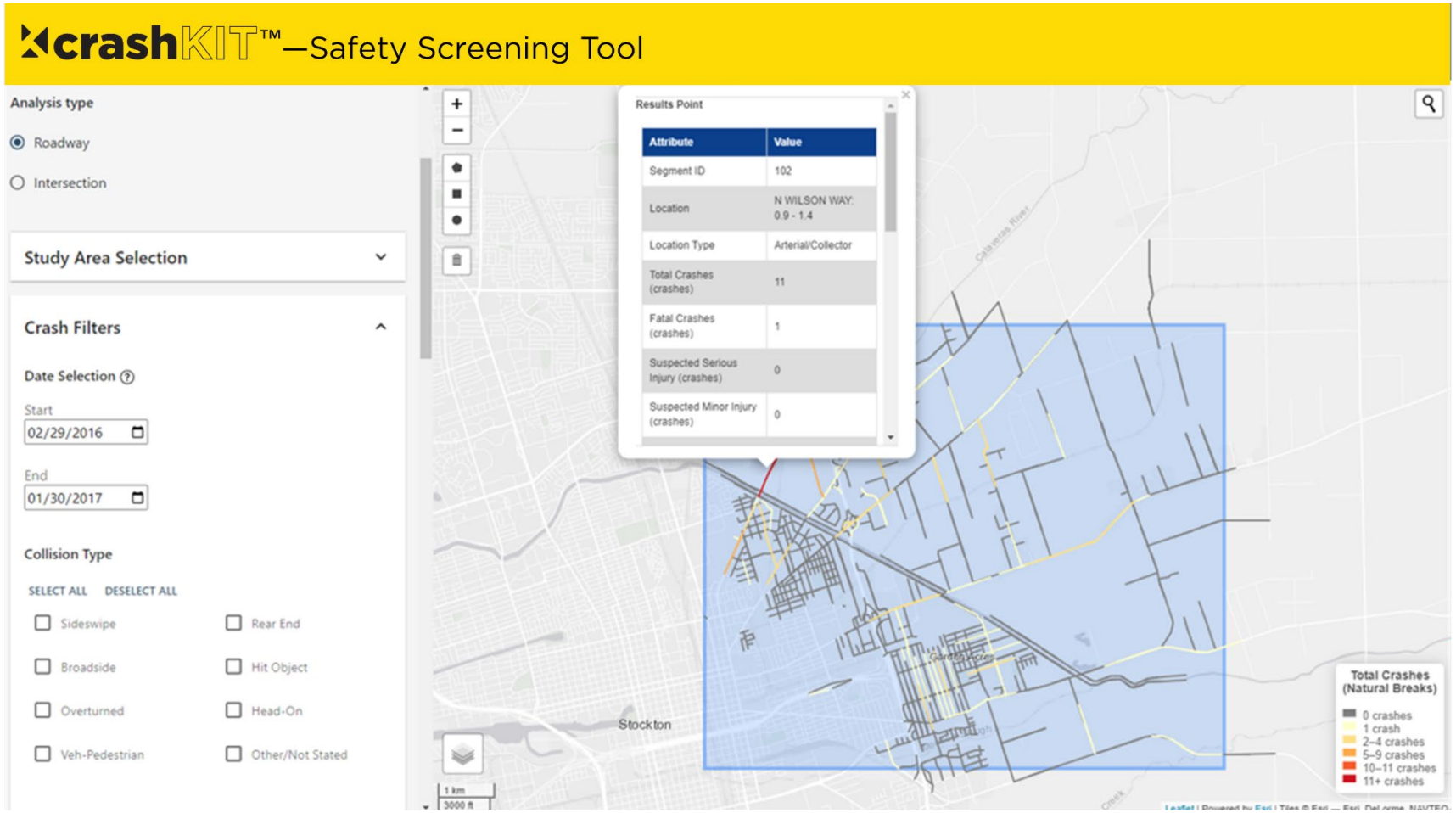
Safety Screening Tool - CrashKIT™

- Online Safety Network Screening Tool
- Identify high crash locations and prioritize safety improvements
- High injury network (HIN)
- Excess expected crash frequency
- Tracking long-term trends and before & after assessment



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Multimodal Analysis Integration in ICE

ICE Stage 1

- **Vehicles**
  - Capacity and Level of Service
  - Safety performance
- **Pedestrians and Bicyclists**
  - Safe origin-destination movements
  - Adequate facility type

ICE Stage 2

- **Vehicles**
  - Delay and queuing analysis
  - Safety modeling
- **Pedestrians and Bicyclists**
  - Operations analysis
  - Design-flag assessment of design elements

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Multimodal Analysis - Guiding Principles

1

Integrate Multimodal Facilities in the Design Process, as opposed to '*accommodating*' pedestrians and bicyclists at later stages

2

Allow **comparison** of alternative intersections and interchanges (A.I.I.) with 'conventional' designs

3

Focus on **design elements** of the intersection, rather than intersection form

4

Follow a **performance-based** design process

What makes an Intersection Safe for Pedestrians and Bicyclists?

- Crossing of few number of lanes at a time
- Use of short cycle lengths (if signalized)
- Crossing one direction of traffic at a time
- Users make one decision at a time
- Slow vehicle speeds at crossings
- Adequate crossing opportunities in the form of gaps or stops/yields
- Intuitive to use

Motivation for NCHRP Report 948

- Pedestrian and Bicyclist Crashes more rare than vehicular crashes
  - Reduced exposure
  - Underreporting
- Difficult to develop predictive safety
  - Some Crash Modification Factors (CMFs)
  - Limited Safety Performance Functions (SPFs)
- Desire to programmatically enhance pedestrian and bicyclist safety
  - Systemic Safety Strategies
  - Designing Safe Systems

20 Questions for Pedestrian and Bicyclist Safety

Motor Vehicle Right Turns	Uncomfortable/ Tight Walking Environment	Nonintuitive Motor Vehicle Movements	Crossing Yield- or Uncontrolled Vehicle Paths
Indirect paths	Executing Unusual Movements	Multilane Crossings	Long Red Times
Undefined Crossing at Intersections	Motor Vehicle Left Turns	Intersecting Driveways and Side Streets	Sight Distance for Gap Acceptance Movements
Grade Change	Riding in Mixed Traffic	Bicycle Clearance Times	Lane Change Across Motor Vehicle Lane(s)
Channelized Lanes	Turning Motorists Crossing Bicycle Paths	Riding Between Travel Lanes, Lane Additions, or Lane Merges	Off-tracking Trucks in Multilane Curves

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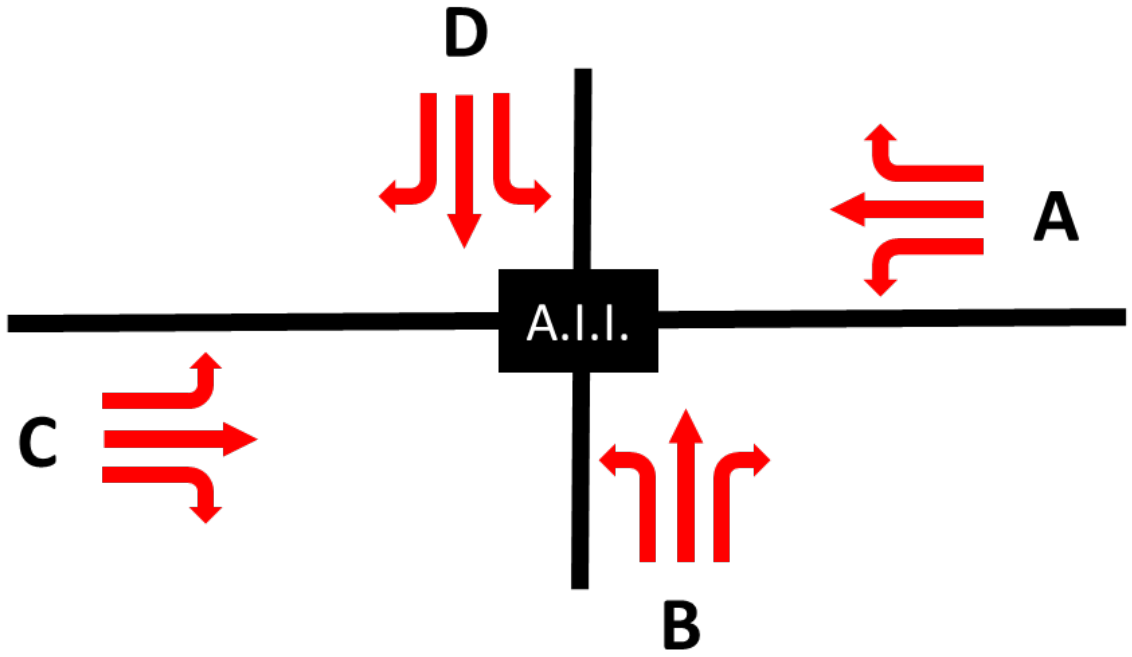
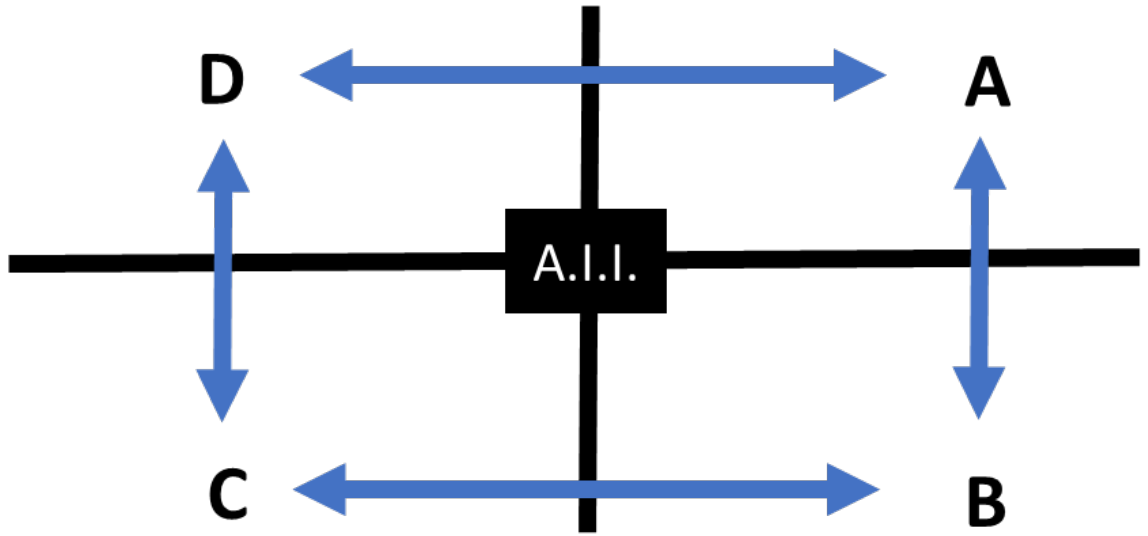
Yellow vs. Red Flags

Yellow Flags, for design elements negatively affecting user comfort (in other words, increasing user stress) or the quality of the walking or cycling experience.

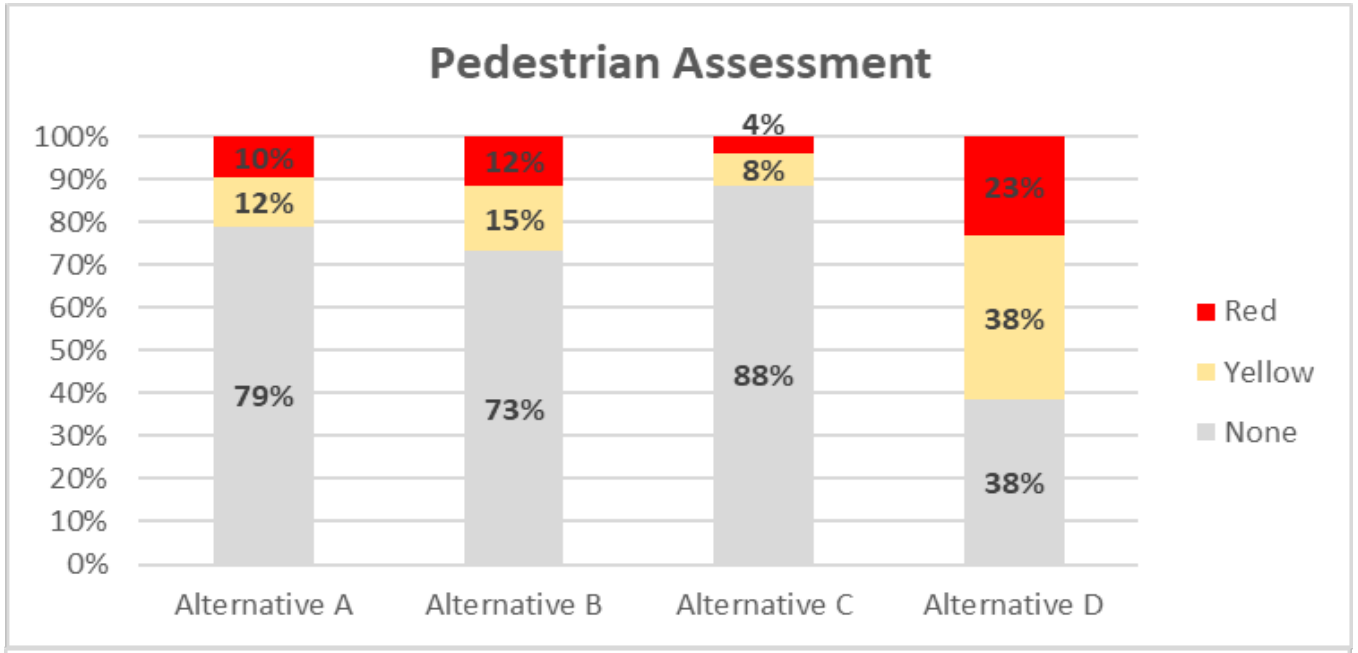
Red Flags, for design elements that are directly related to a safety concern for pedestrians or bicyclists.

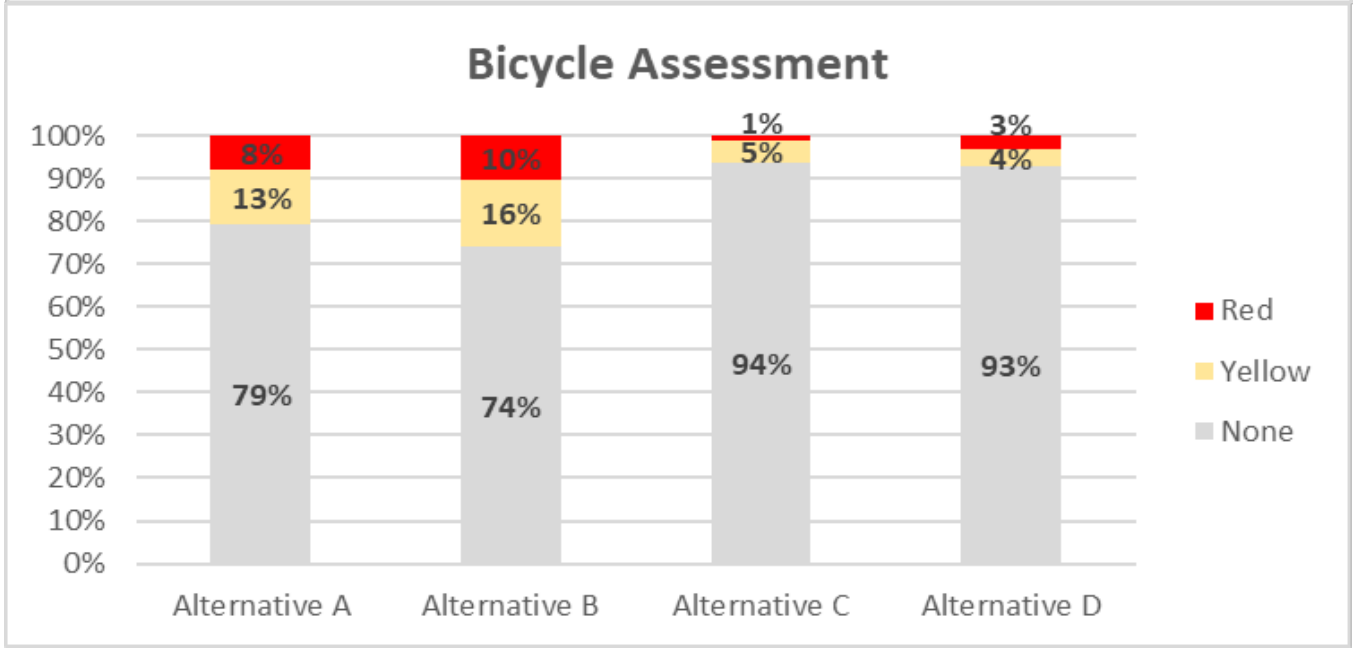




Applying Design Flag Checks

Goal: Quantitative Alternatives Assessment





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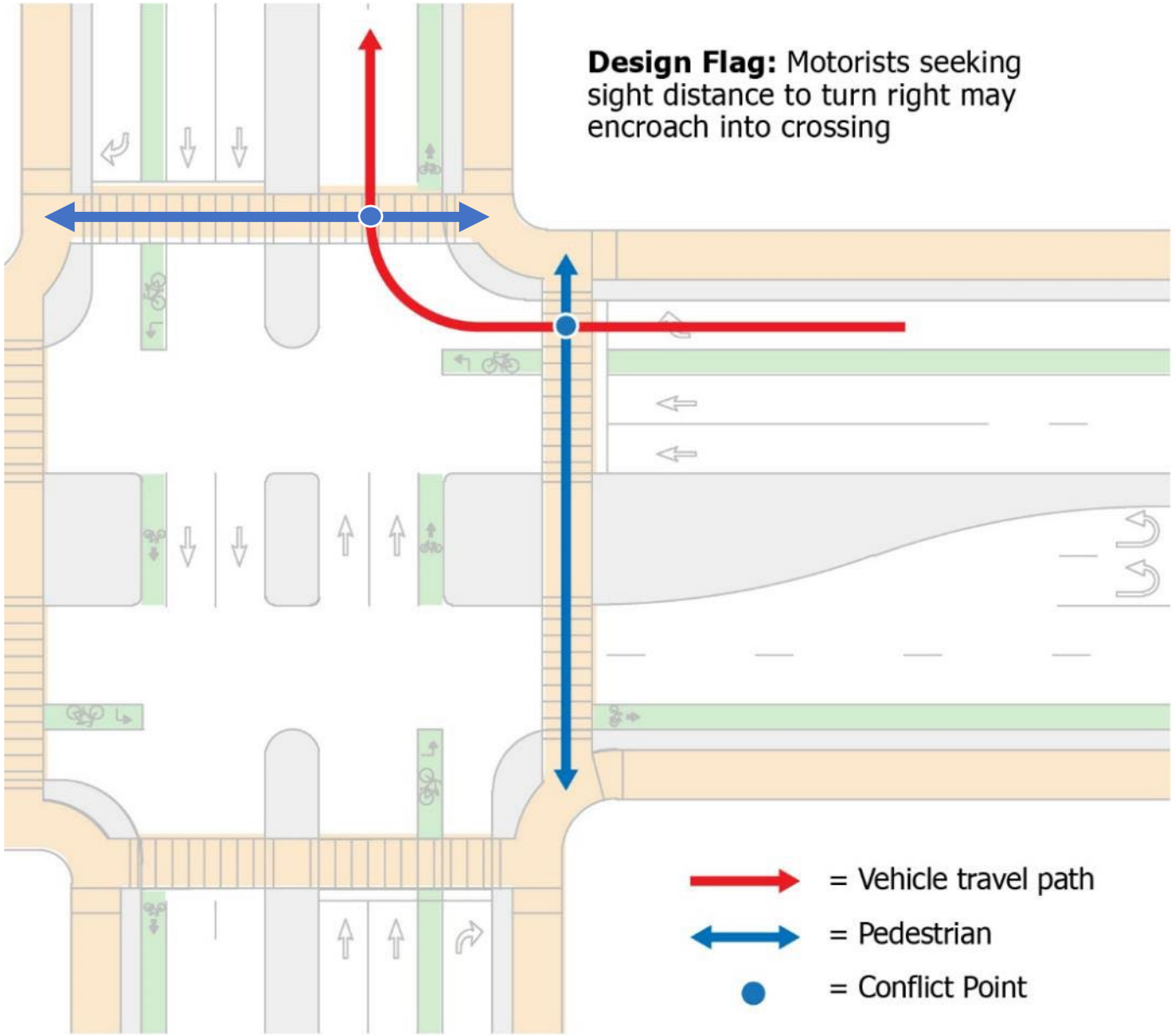
Design Flag 1: Motor Vehicle Right Turns



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Design Flag 1 at Conventional Intersections

Vehicles permitted to turn right across marked crosswalks.

Intersection with channelized turn lanes.

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Design Flag #1: Potential Treatments

Right-Turn-on-Red Restriction

Leading Pedestrian Interval

Separating Driver Decisions & Reducing Speed

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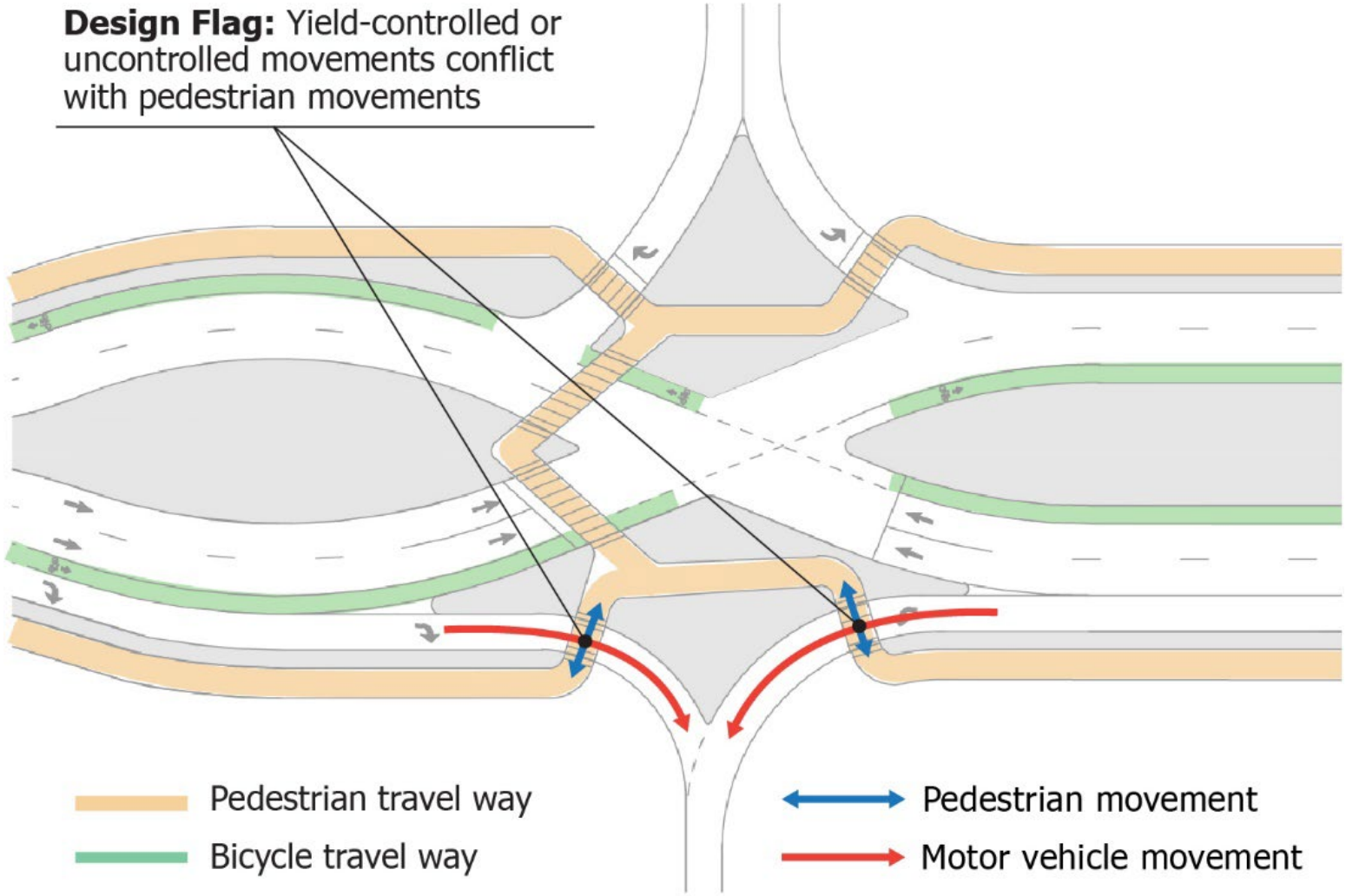
Design Flag 4: Crossing Yield- or Uncontrolled Vehicle Paths



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Design Flag 4 at Conventional Intersection

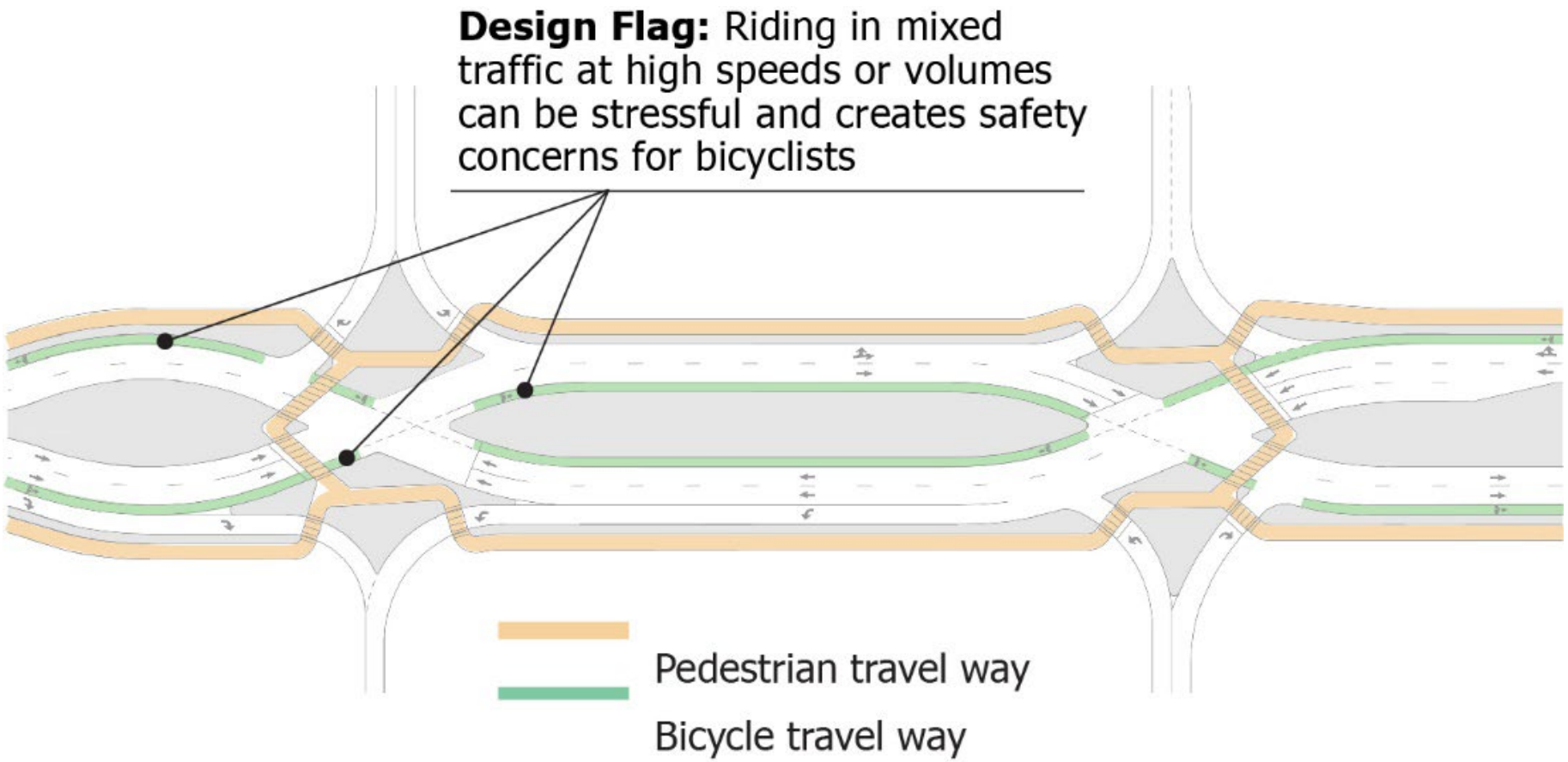
Design Flag #4: Potential Treatments

Rectangular Rapid-Flashing Beacon

Raised Crosswalk

Pedestrian Hybrid Beacon

Design Flag #14 – Riding in Mixed Traffic



Design Flag 14 at Conventional Intersection

Design Flag #14: Potential Treatments

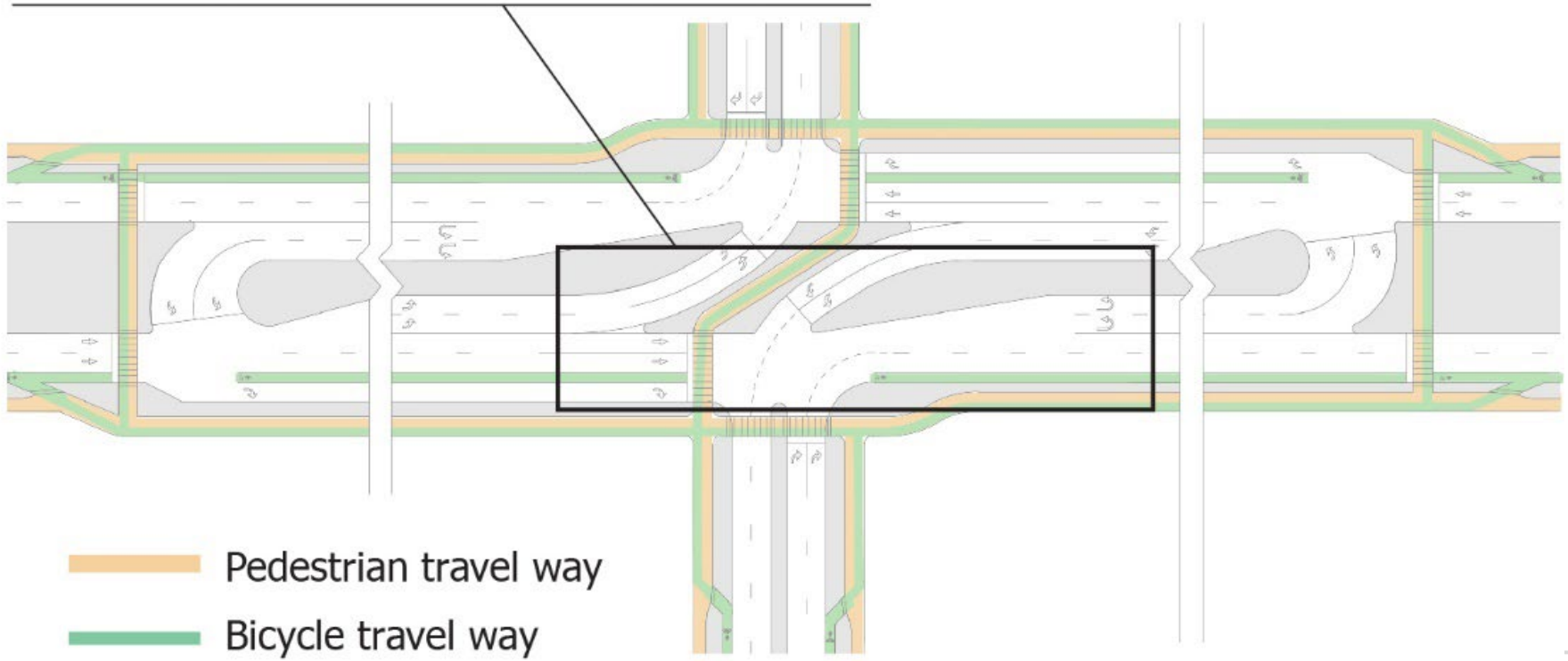
Separated Bike Lane

Shared-Use Path

Reduced Speed Environment

Design Flag #16: Lane Change Across Motor Vehicle Travel Lane

Design Flag: On-street bicyclists trying to turn left would need to cross over motor vehicle travel lanes with considerable speed differential. *(Note that off-street facilities are also provided in this design, mitigating the design flag)*



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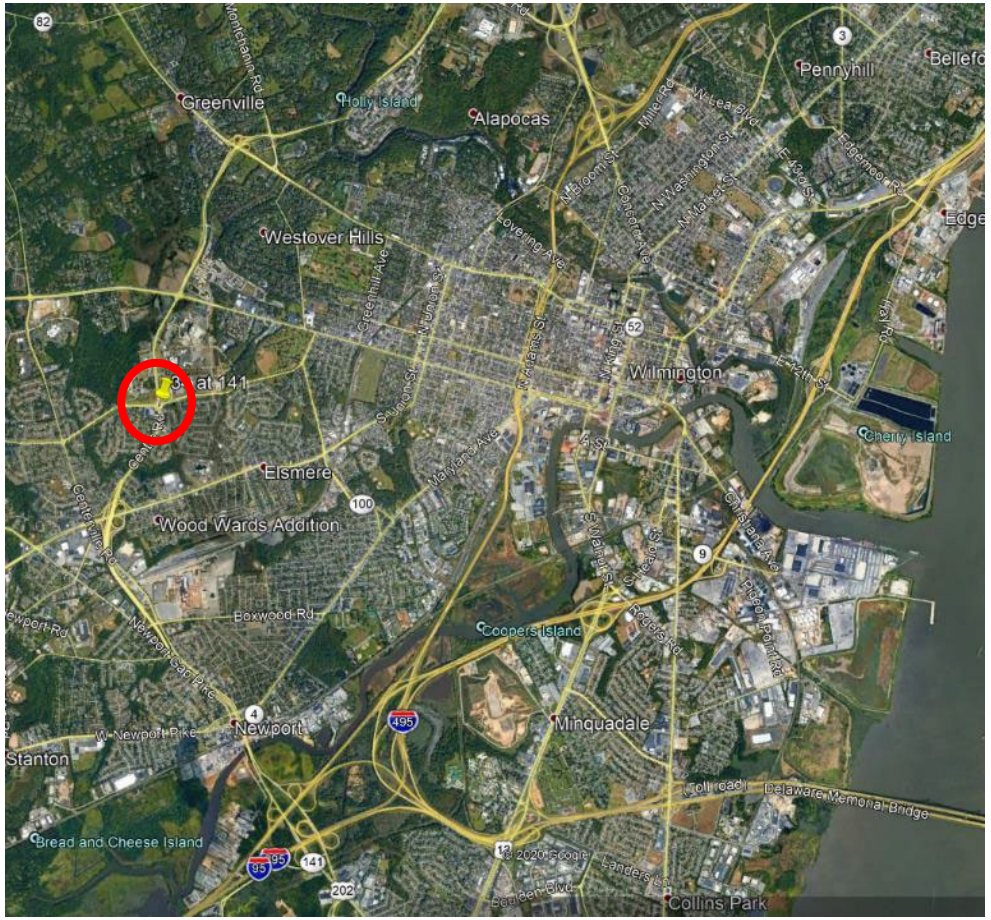
Design Flag 16 at Conventional Intersection

Design Flag #16: Potential Treatments

Two-Stage Left Turn Box at Intersection

Ramp to move cyclists to sidewalk level before intersection

Case Study Application:
Faulkland Rd (34) at Centre Rd. (141), Wilmington, DE



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Example application (Wilmington, DE)

Existing Conditions

- **Motor Vehicle Right Turns**
- Tight Walking Environment
- **Crossing Yield Control Path**
- **Multilane Crossing**
- Long Red Times
- **Intersecting Driveways**
- **Sight Distance**
- **Riding in Mixed Traffic**
- **Bicycle Clearance Times**
- **Lane Change Across Vehicle Lanes**
- **Channelized Lanes**
- Motorist Crossing Bike Path
- Riding Between Travel Lanes

Results: Existing Conditions

- **Motor Vehicle Right Turns**
- Tight Walking Environment
- **Crossing Yield Control Path**
- **Multilane Crossing**
- Long Red Times
- **Intersecting Driveways**
- **Sight Distance**
- **Riding in Mixed Traffic**
- **Bicycle Clearance Times**
- **Lane Change Across Vehicle Lanes**
- **Channelized Lanes**
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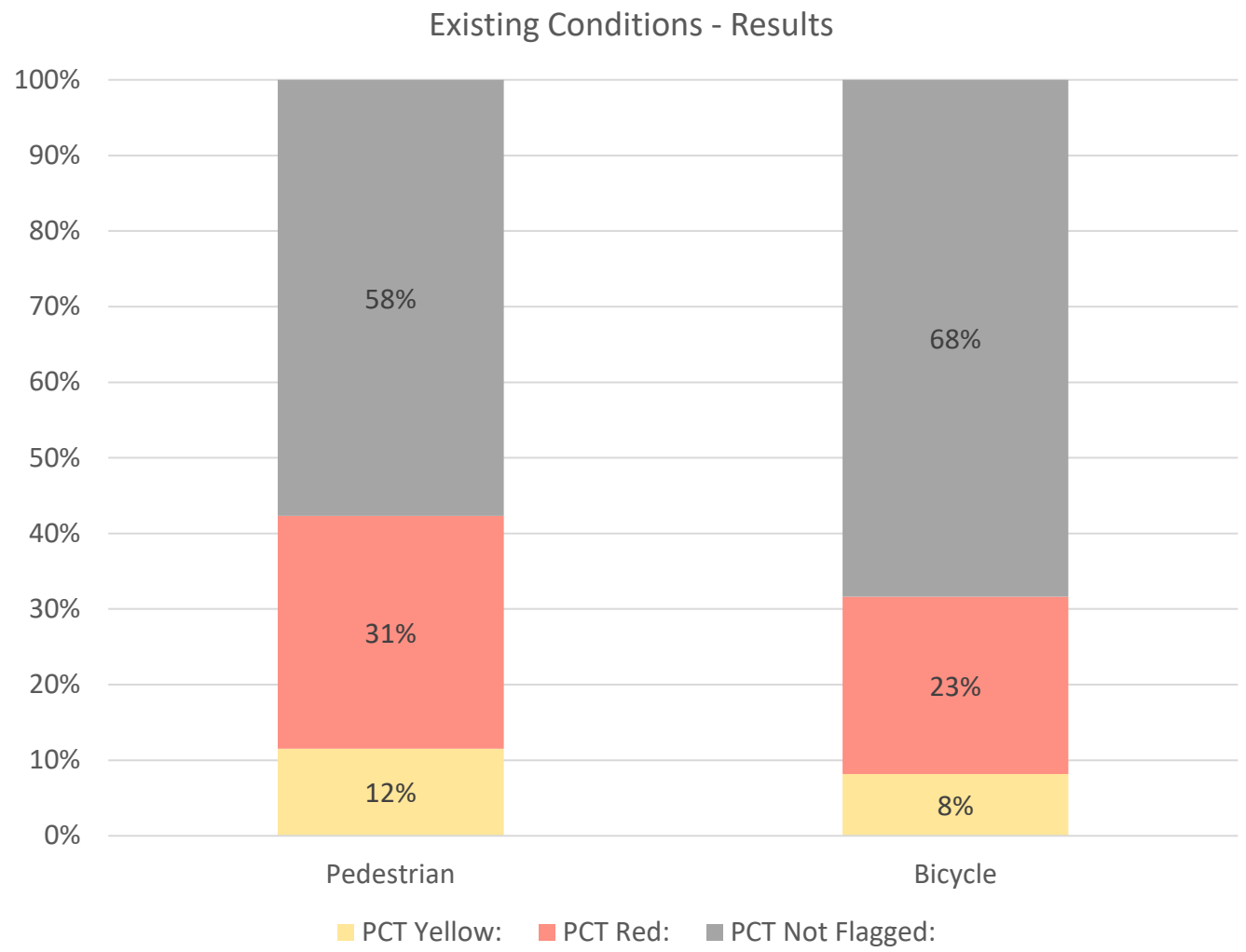
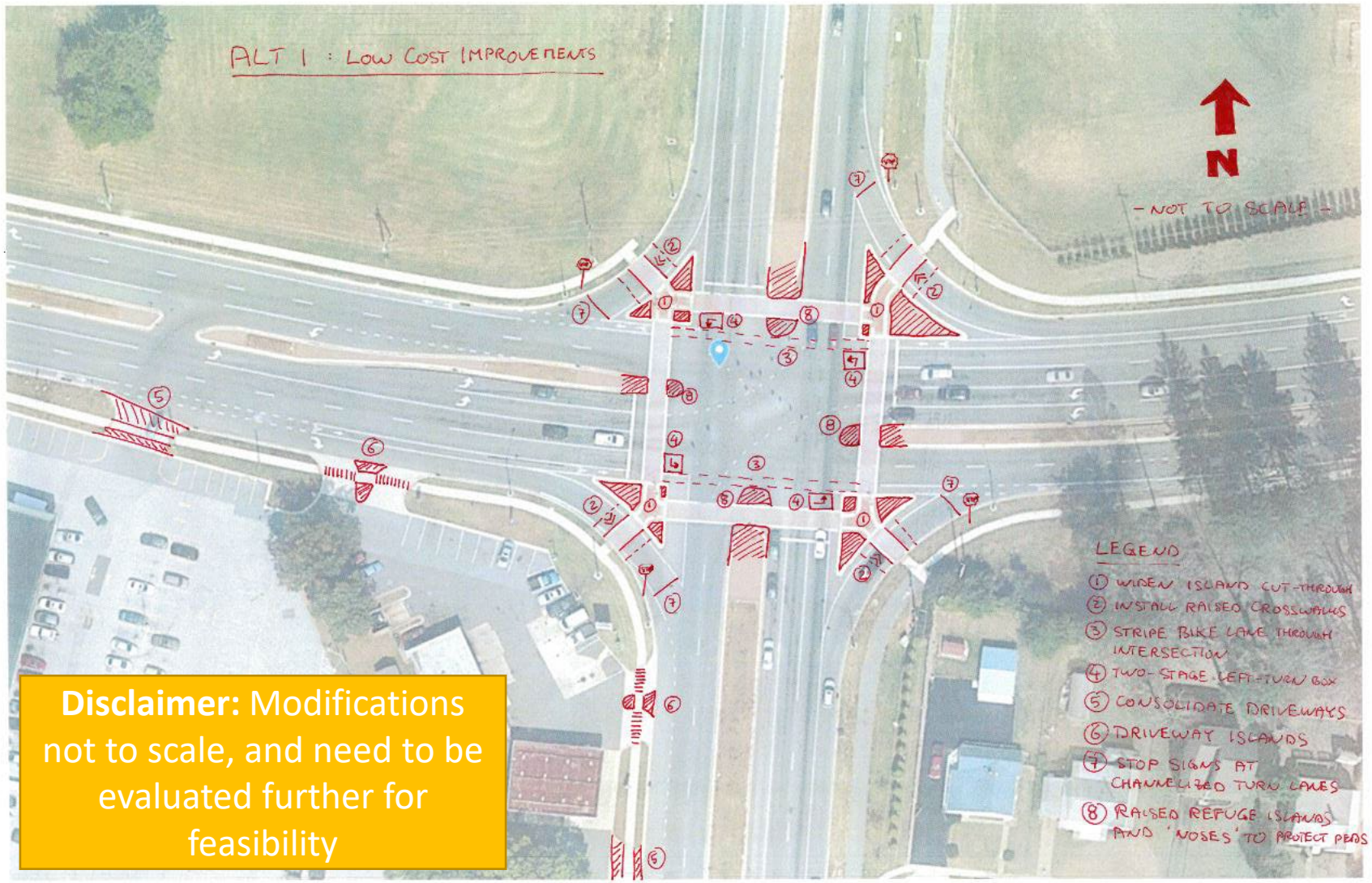


Concept 1: Low-Cost Improvements



Disclaimer: Modifications not to scale, and need to be evaluated further for feasibility

1. Widen Island Cut-Throughs
2. Install Raised Crosswalks
3. Stripe Bike-Lane Through Intersection
4. Add Two-Stage Left-Turns
5. Consolidate Driveways
6. Build Driveway Islands
7. Install Stop Signs at Channelized Turn Lane Exits
8. Raised Refuge Islands and 'noses' to protect pedestrians

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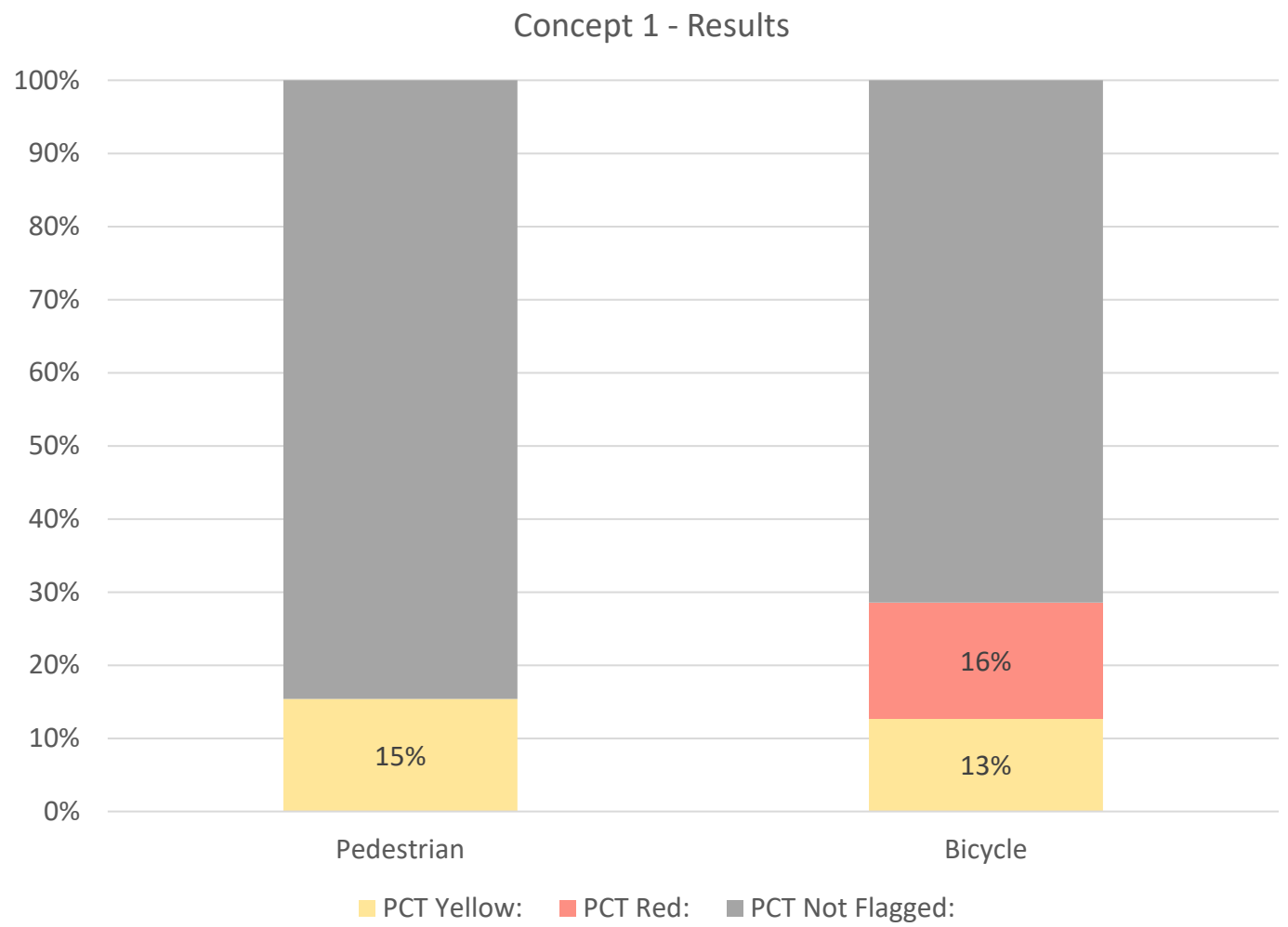
Results: Concept 1 – Low Cost Improvements

- ~~Motor Vehicle Right Turns~~
- ~~Tight Walking Environment~~
- **Crossing Yield Control Path**
- Multilane Crossing*
- Long Red Times
- Intersecting Driveways*
- ~~Sight Distance~~
- **Riding in Mixed Traffic**
- **Bicycle Clearance Times**
- ~~Lane Change Across Vehicle Lanes~~
- **Channelized Lanes***
- Motorist Crossing Bike Path
- Riding Between Travel Lanes



*Mitigated but not eliminated

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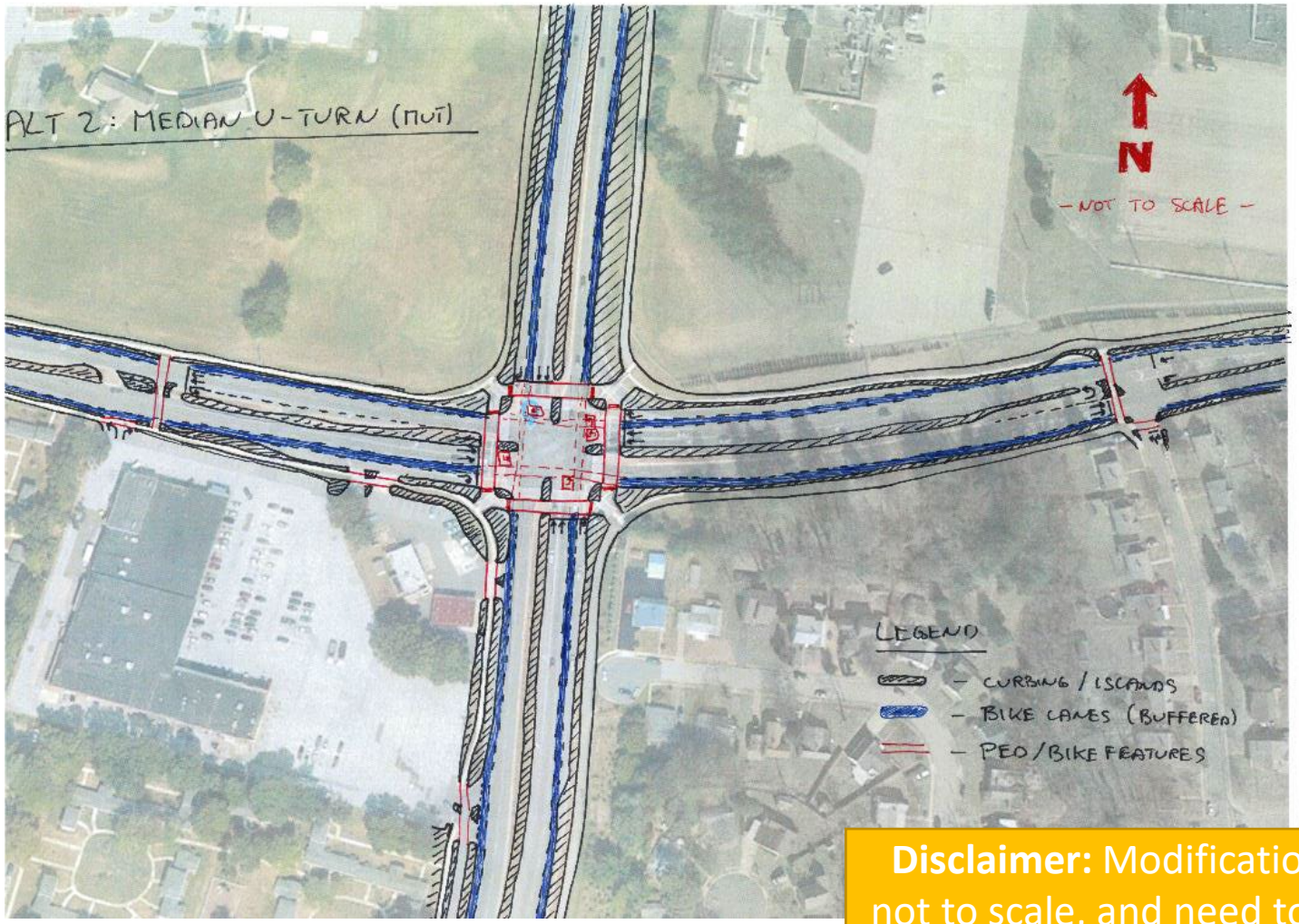
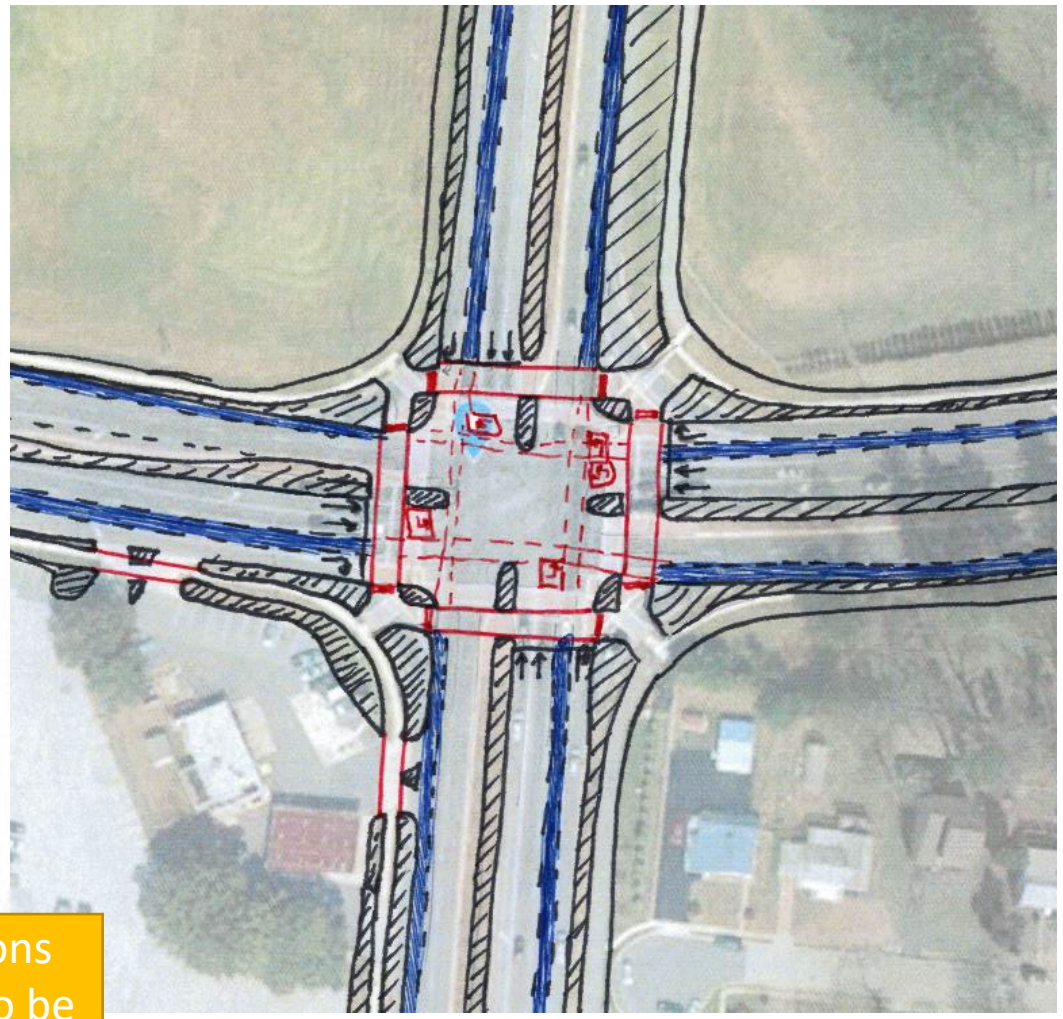
Concept 2: Median U-Turn (MUT)

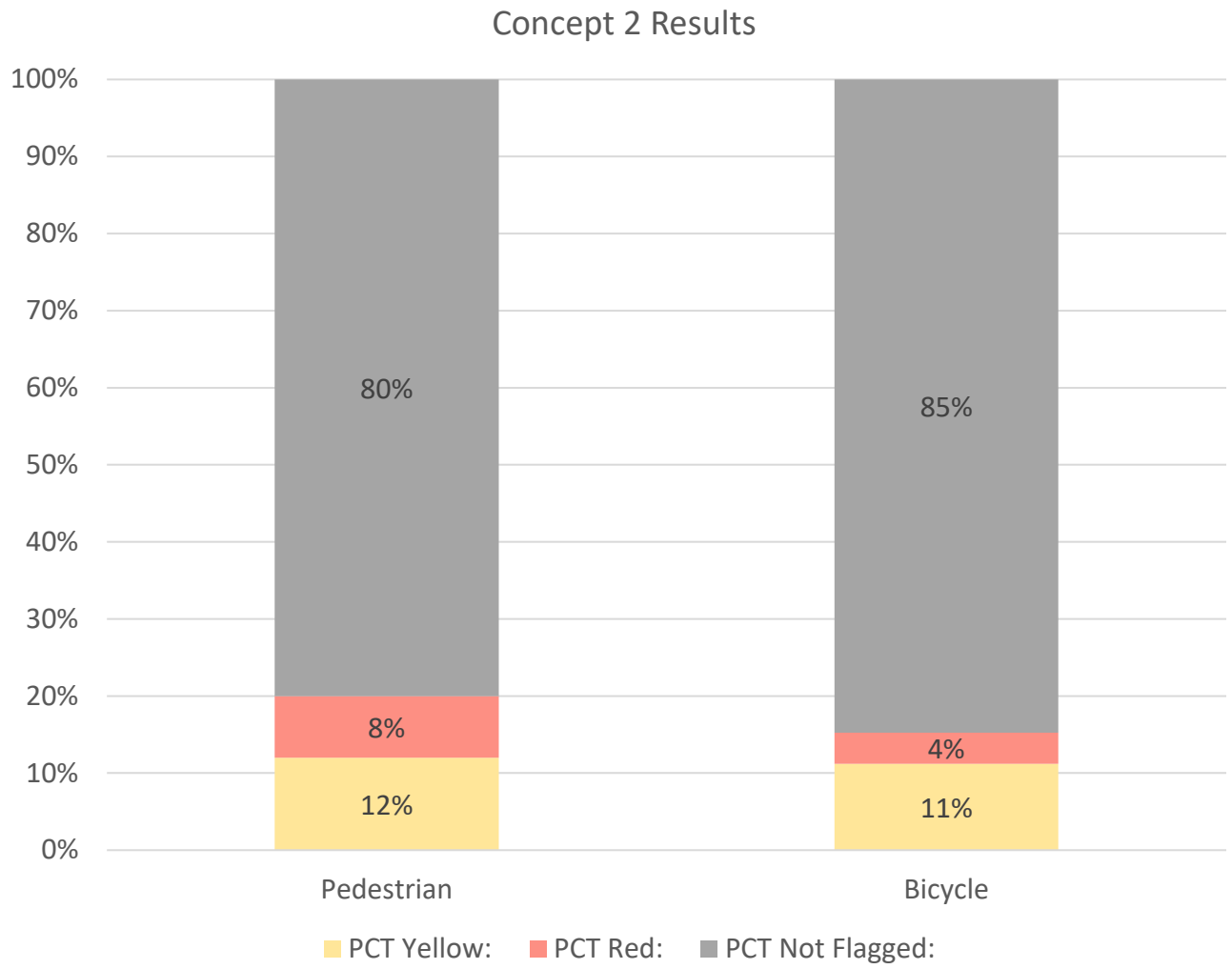




Disclaimer: Modifications not to scale, and need to be evaluated further for feasibility

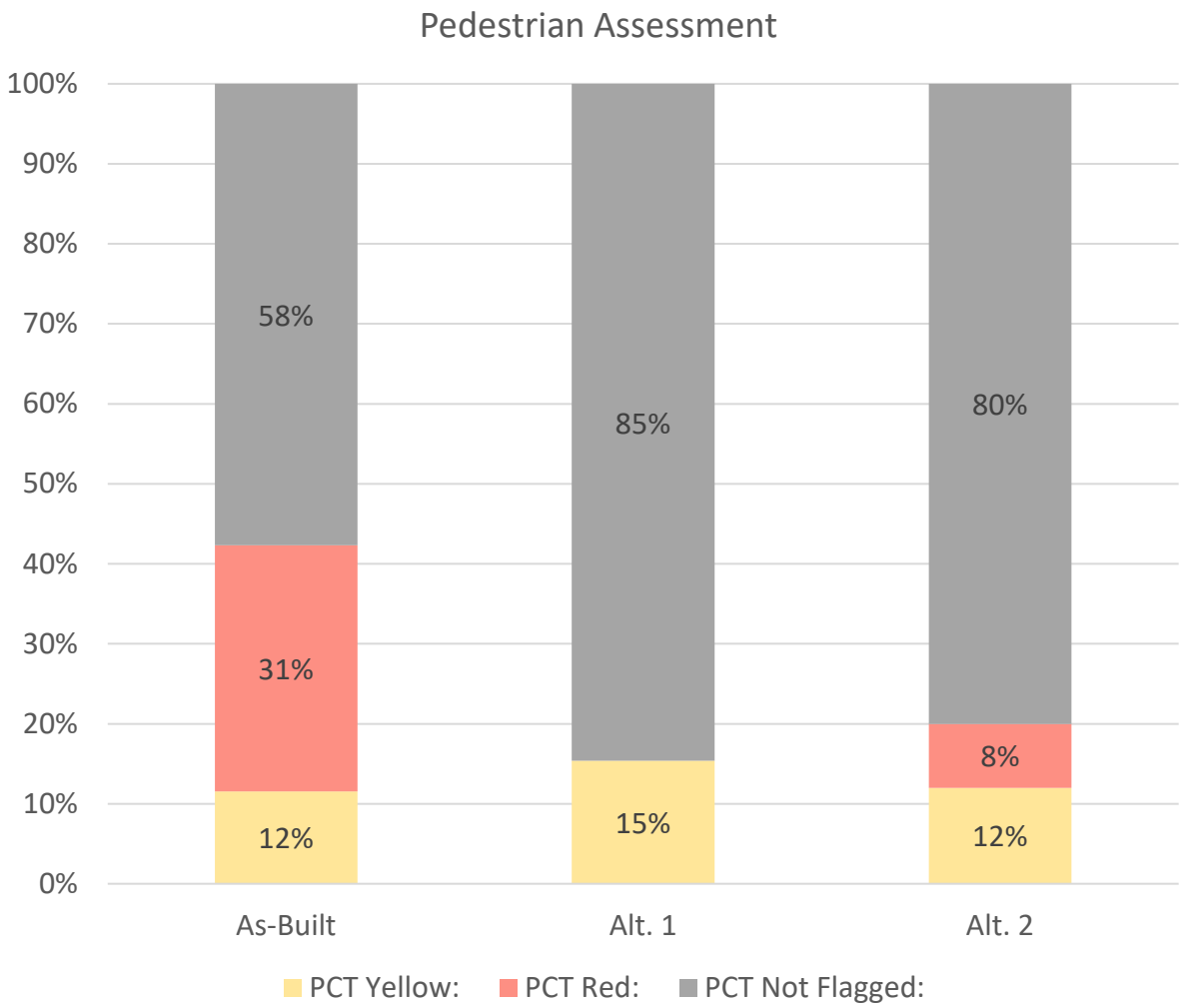
Results: Alt. 2 – Median U-Turn (MUT)

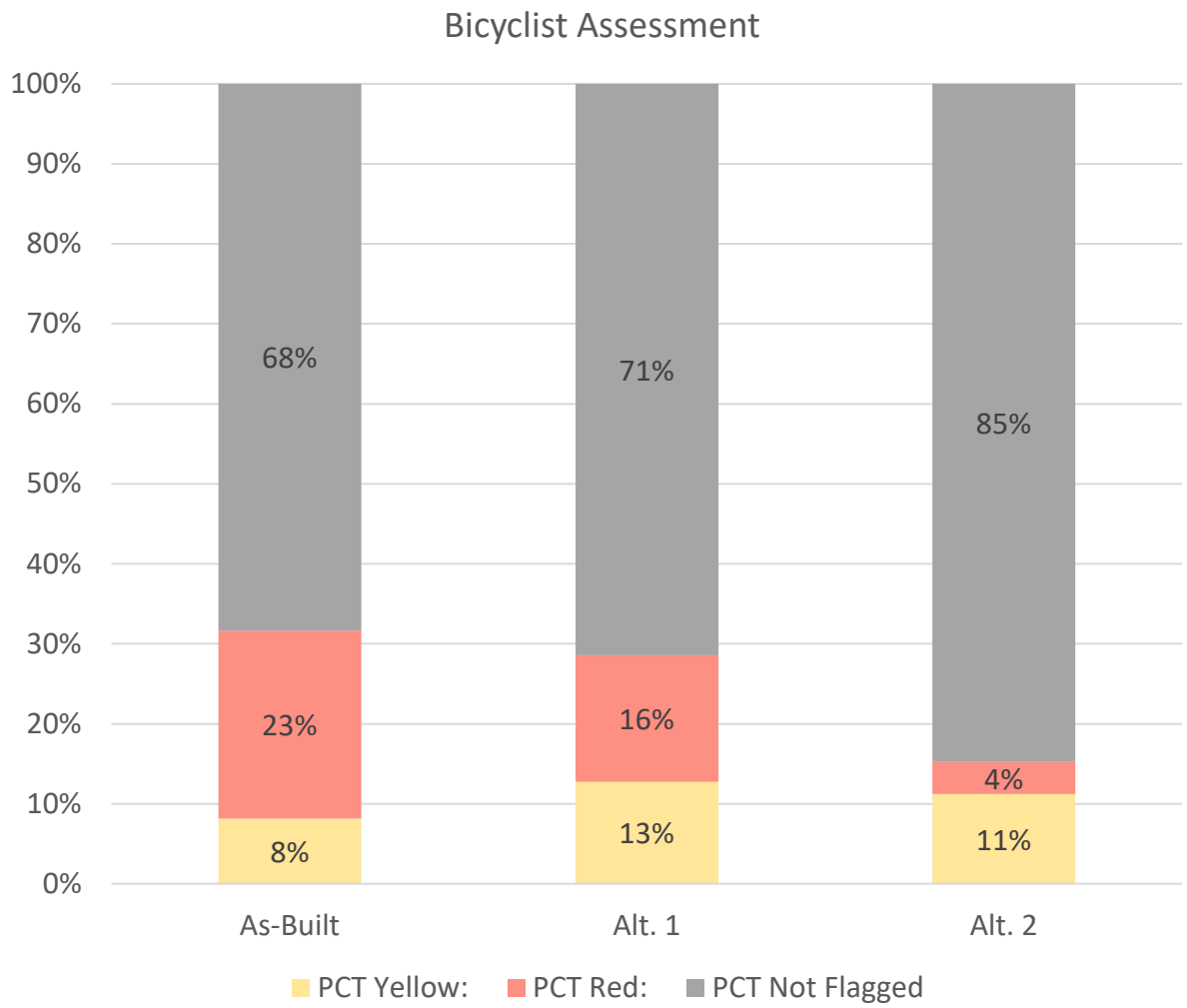
- **Motor Vehicle Right Turns**
- ~~Tight Walking Environment~~
- ~~Crossing Yield Control Path~~
- Multilane Crossing*
- **Long Red Times***
- Intersecting Driveways*
- ~~Sight Distance~~
- ~~Riding in Mixed Traffic~~
- ~~Bicycle Clearance Times~~
- ~~Lane Change Across Vehicle Lanes~~
- ~~Channelized Lanes~~
- Motorist Crossing Bike Path
- Riding Between Travel Lanes



*Mitigated but not eliminated

Results





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Design Flag Assessment Method –

20 Questions for Pedestrian and Bicyclist Safety

Motor Vehicle Right Turns	Uncomfortable/ Tight Walking Environment	Nonintuitive Motor Vehicle Movements	Crossing Yield- or Uncontrolled Vehicle Paths
Indirect paths	Executing Unusual Movements	Multilane Crossings	Long Red Times
Undefined Crossing at Intersections	Motor Vehicle Left Turns	Intersecting Driveways and Side Streets	Sight Distance for Gap Acceptance Movements
Grade Change	Riding in Mixed Traffic	Bicycle Clearance Times	Lane Change Across Motor Vehicle Lane(s)
Channelized Lanes	Turning Motorists Crossing Bicycle Paths	Riding Between Travel Lanes, Lane Additions, or Lane Merges	Off-tracking Trucks in Multilane Curves

Design Keys to Success

1

Integrate multimodal facilities early in the design process, and check for safety concerns throughout the evolution of the design.

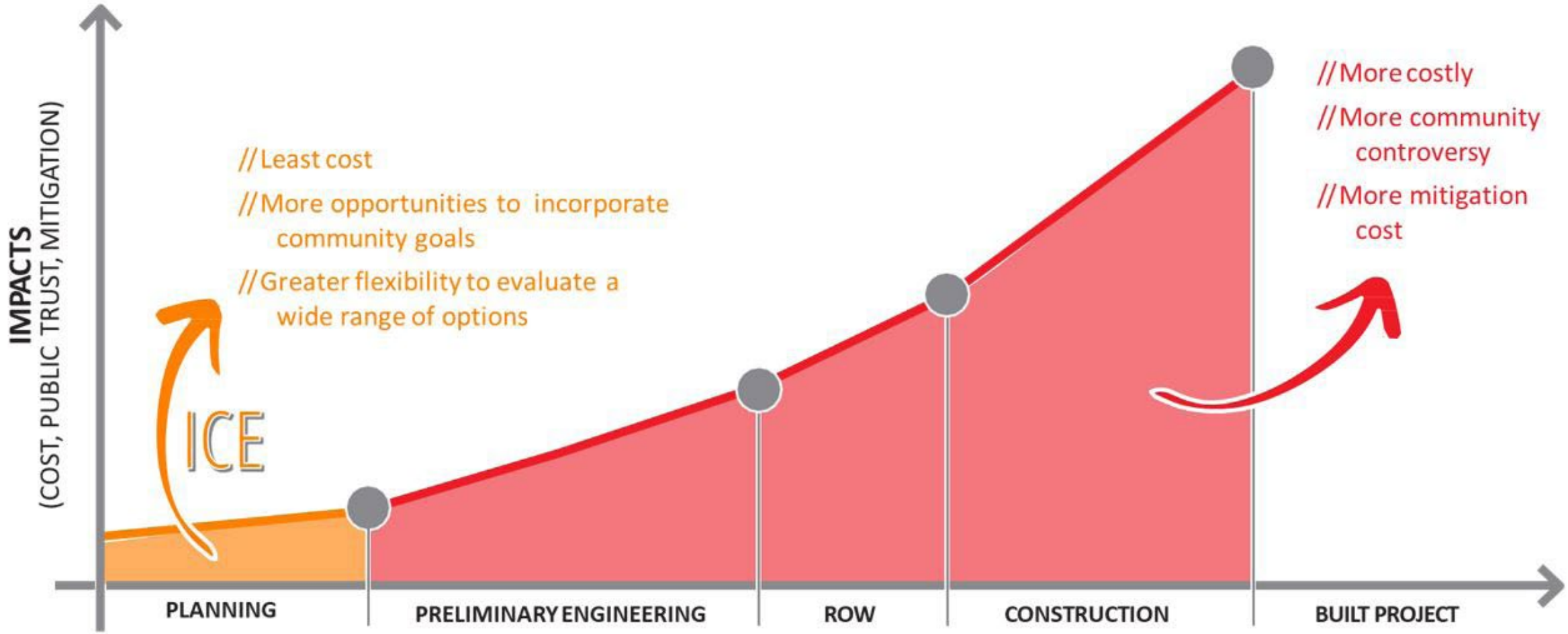
2

Identify **project priorities**, understanding that tradeoffs will be necessary

3

Recognize while it is unlikely to eliminate all flags, **assessing the design at each stage** provides the most opportunity to minimize flag count

Think ‘Early and Often’



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Discussion and Questions

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