NORTH CAROLINA
Department of Transportation

Fewer Crashes and Less Delay with New Intersection Designs

For NC Vision Zero

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Intersections Matter

Roadway		2014-18 average NC crashes per 100 million veh-mile
Rural interstate		67
Urban interstate		128
Urban primary	4 or more lanes, divided, no access control	319
	4 or more lanes, divided, partial access control	217
	4 or more lanes, divided, full access control	121

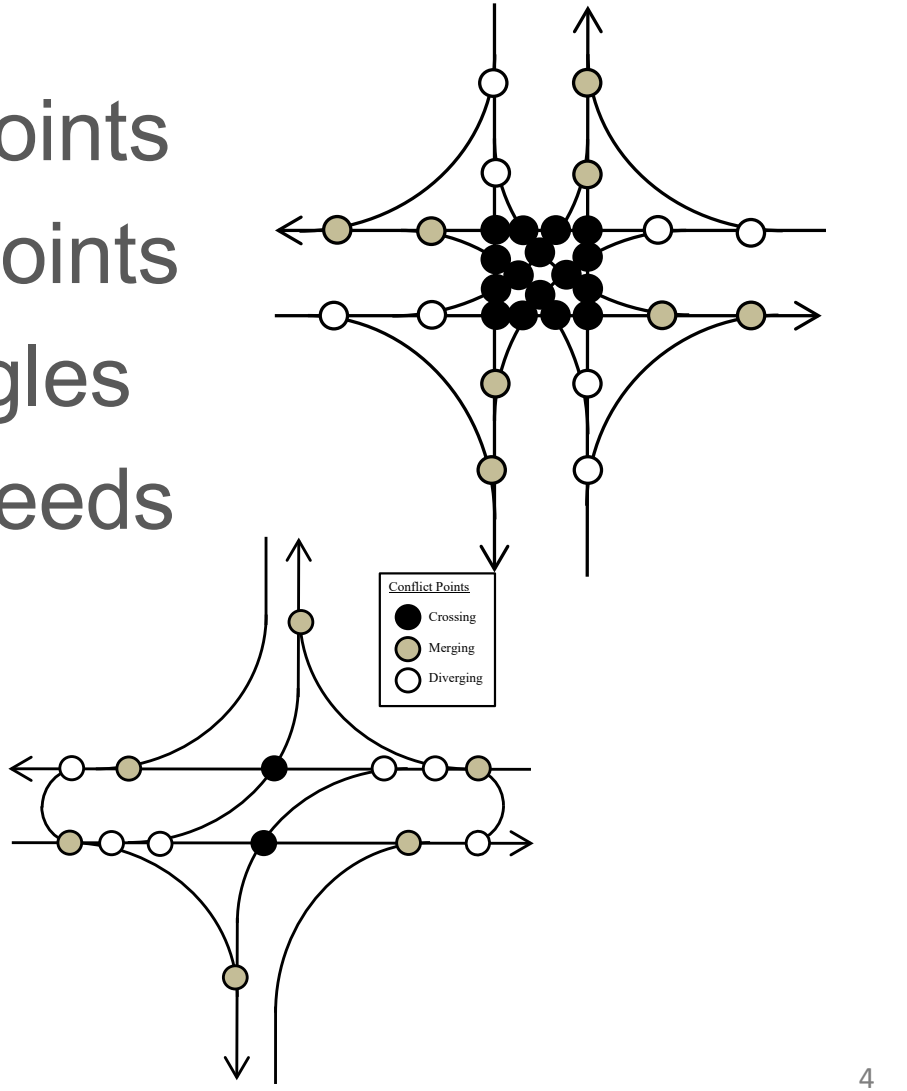
Intersections Matter

In 2018, NC Statewide

- 138,000 crashes at intersections
  - More than reported “non-intersection” crashes
- 43,000 injury crashes at intersections
  - Compared to 36,000 “non-intersection”
- 400 fatal crashes at intersections
  - Compared to 900 “non-intersection”

Safer Intersection Principles

1. Minimize conflict points
2. Separate conflict points
3. Control conflict angles
4. Reduce conflict speeds



The Safest Intersection: All-Way Stop Control

- Average crash modification factor (CMF) = 0.40 for all crashes, 0.38 for injury crashes
  - Compared to conventional signal
- Speed control
- Cheap

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Problem: low capacity

The Next-Safest Intersection: Roundabout

- Average CMF = 0.74 for all crashes, 0.45 for injury crashes
- Control number of conflicts, angles, speeds

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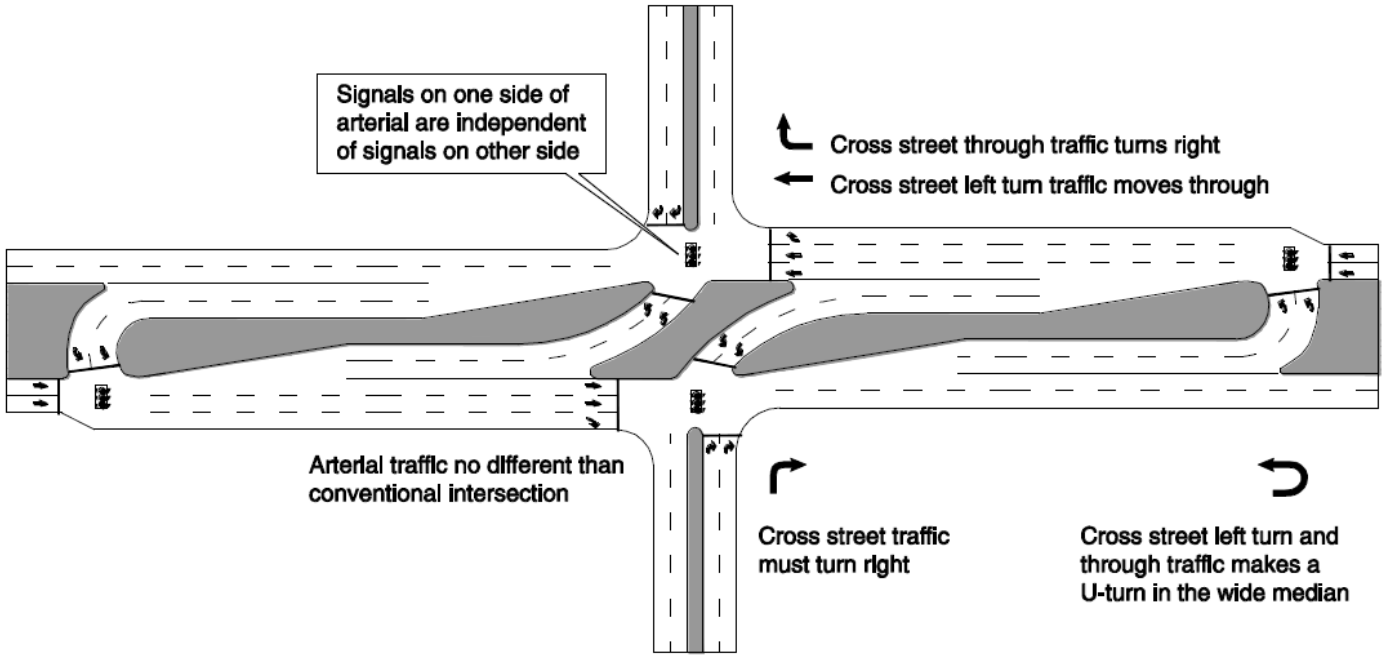
Problem: capacity better but still low

We Need Other Alternatives

- As many safety features as possible
- Higher capacity
- Good progression through signals
- Good for pedestrians and bicyclists
- Good for access
- Low cost and impacts

Where Arterial Meets Minor Road-- Reduced Conflict Intersection (RCI)

- A.k.a. RCUT, superstreet, j-turn
- Great safety
  - Unsignalized CMF 0.54 all crashes, 0.37 injury
  - Signalized CMF 0.85 all crashes, 0.78 injury



Where Arterial Meets Minor Road-- Reduced Conflict Intersection (RCI)

- Could provide higher capacity
- Perfect progression
- Good for pedestrians

- NC is world's leader
- Potential for many more

Problem: low minor street capacity

Where Two Arterials Meet—Median U-Turn (MUT)

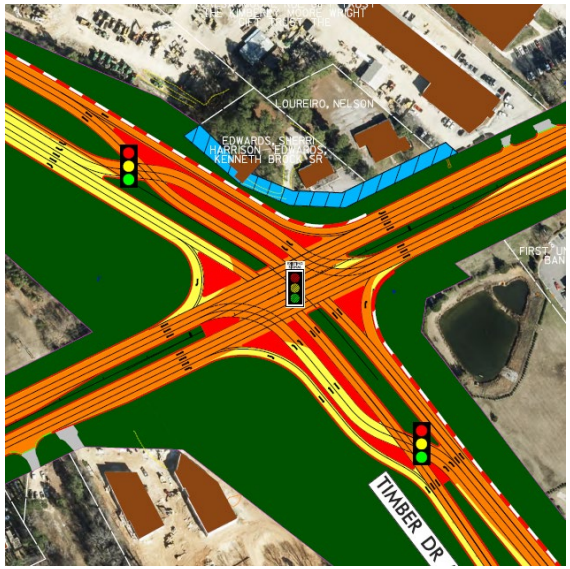
- Good safety record, CMF ~ 0.85 all crashes
- Good capacity
- Good for pedestrians
- Three open in NC

Weakness: Needs low left turn demand

Where Two Arterials Meet—Continuous Flow Intersection (CFI)

Where Two Arterials Meet—CFI

- Good safety record, CMF = 0.88 all crashes
- Highest capacity of any at-grade design
  - Comparable to grade-separated solutions
- First in NC opened Fall 2019



Weaknesses:
Pedestrians,
business access

Where Two Arterials Meet—Quadrant Roadway

- Safety unknown so far
- Excellent capacity
- Good for pedestrians
- Good for business access
- One open in NC

Weakness: Potential driver confusion

Where Two Arterials Meet-- Grade-Separated Intersection

- Should be relatively safe
  - No empirical evidence though
- Great capacity
- Could be good for pedestrians and access
- Don't use an interchange design

Weakness: high costs and impacts

Partial and Hybrid Designs

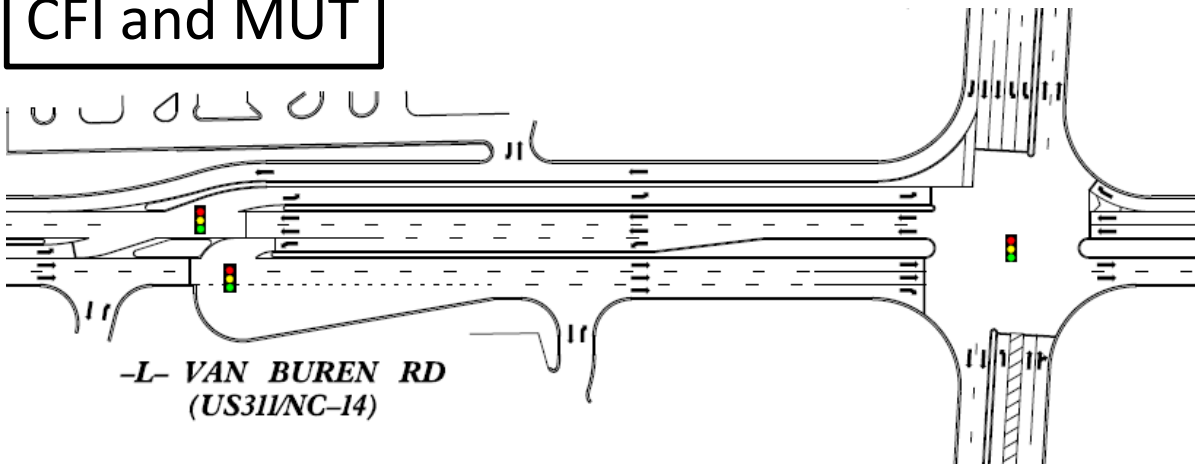
Reverse RCI

Bowtie

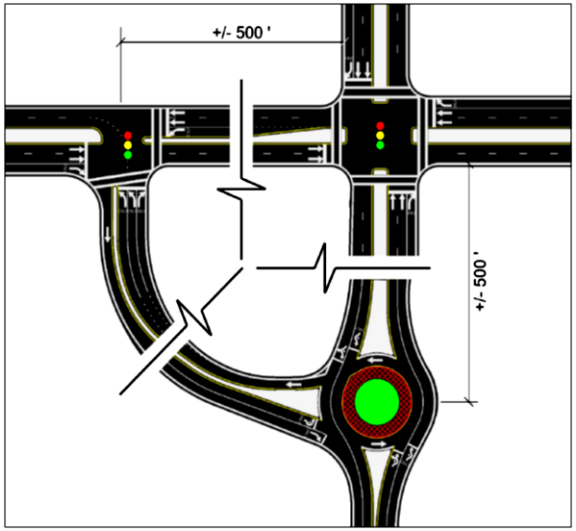
Partial and Hybrid Designs

Partial MUT

CFI and MUT



Quadrant and roundabout



Safest Feasible Intersection Design (SAFID) Chart, All Crashes

				Minor street						
			Number through lanes:	2				4		6 or 8
Major street			Low AADT:	0	5,000	7,500	10,000	10,000	25,000 and above	Any
Number through lanes	Low AADT	High AADT	High AADT:	5,000	7,500	10,000	15,000	25,000		
2	0	7,500		**All-way stop**	**All-way stop**	n/a	n/a	n/a	n/a	n/a
	7,500	15,000		**One-lane roundabout**	**One-lane roundabout**	**One-lane roundabout**	**One-lane roundabout***	n/a	n/a	n/a
4	10,000	15,000		**Unsignalized RCI**	**Unsignalized RCI**	**Unsignalized RCI**	**Signalized RCI**	**Signalized RCI**	n/a	n/a
	15,000	20,000		**Unsignalized RCI**	**Unsignalized RCI**	**Signalized RCI**	**Signalized RCI**	**Signalized RCI**	n/a	n/a
	20,000	25,000		**Unsignalized RCI**	**Signalized RCI**	**Signalized RCI**	**Signalized RCI**	**Signalized RCI**	n/a	n/a
	25,000 and above			**Unsignalized RCI**	**Signalized RCI**	**Signalized RCI**	**Signalized RCI**	**Signalized RCI**	**Median u-turn**	n/a
6 or 8	Any			**Unsignalized RCI**	**Signalized RCI**	**Signalized RCI**	**Signalized RCI**	**Signalized RCI**	**Median u-turn**	**Median u-turn**

* One-lane roundabouts are generally feasible if the combined AADT is less than 25,000. If a one-lane roundabout is infeasible a signal is the safest feasible design.

SaFID Chart, Injury Crashes

				Minor street						
			Number through lanes:	2				4		6 or 8
Major street			Low AADT:	0	5,000	7,500	10,000	10,000	25,000 and above	Any
Number through lanes	Low AADT	High AADT	High AADT:	5,000	7,500	10,000	15,000	25,000		
2	0	7,500		**All-way stop**	**All-way stop**	n/a	n/a	n/a	n/a	n/a
	7,500	15,000		**One-lane roundabout**	**One-lane roundabout**	**One-lane roundabout**	**One-lane roundabout***	n/a	n/a	n/a
4	10,000	15,000		**Unsignalized RCI**	**Unsignalized RCI**	**Unsignalized RCI**	**Two-lane roundabout**	**Two-lane roundabout**	n/a	n/a
	15,000	20,000		**Unsignalized RCI**	**Unsignalized RCI**	**Two-lane roundabout**	**Two-lane roundabout**	**Two-lane roundabout**	n/a	n/a
	20,000	25,000		**Unsignalized RCI**	**Two-lane roundabout**	**Two-lane roundabout**	**Two-lane roundabout**	**Two-lane roundabout****	n/a	n/a
	25,000 and above			**Unsignalized RCI**	**Two-lane roundabout**	**Two-lane roundabout**	**Two-lane roundabout**	**Two-lane roundabout****	**Median u-turn**	n/a
6 or 8	Any			**Unsignalized RCI**	**Median u-turn**	**Median u-turn**	**Median u-turn**	**Median u-turn**	**Median u-turn**	**Median u-turn**

* One-lane roundabouts are generally feasible if the combined AADT is less than 25,000. If a one-lane roundabout is infeasible a signal is the safest feasible design.

** Two-lane roundabouts are generally feasible if the combined AADT is less than 45,000. If a two-lane roundabout is infeasible a median u-turn is the safest feasible design

SaFID Should be the Default

- Why start with a less-safe design?
  - Two-way stop never safest in chart
  - Conventional signal almost never safest in chart
- Many reasons not to choose SaFID
- Safety model may not apply
- Safety research is limited
  - No CMFs for grade-separated intersections for example

Public Acceptance

- “Based on what we’ve seen, it doesn’t seem friendly to our business community,” [the Town Manager] told the board.
- An auto parts chain retailer, commenting on a project now in design: “If these entrances are converted to right-in and right-out and customers have to make a u-turn at another location to access the store, I expect the impact to store traffic to be significant. It would be ideal if NCDOT could leave our access points unchanged and focus on adding traffic lanes on this portion instead.”

Our Strategies

- Be opportunistic
- Investigate wide range of alternatives
  - Try to find one that everyone is happy with
- Research
- Educate professionals
- Public relations
- Be consistent
- Compromise when necessary
- Choose “do nothing” alternative if necessary

Compromise When Necessary

Actions agencies can undertake with RCI to satisfy drivers and pedestrians

1. Add crossover
2. Signalize crossover
3. Signalize side street or driveway
4. Use shorter signal cycle
5. Establish slower progression speed
6. Keep full movement signal if it is well-spaced for progression
7. Establish signalized midblock crosswalk
8. Create offset intersection to allow straight crosswalk
9. Use median wide enough for planting
10. Coordinate signals for crossing pedestrians

Actions agencies can undertake with RCI to satisfy drivers

11. Coordinate signals for side street traffic
12. Use reverse RCI or other three-phase signal if it is well-spaced for progression
13. Use continuous green T
14. Keep crossover unsignalized
15. Move u-turn crossover closer to main intersection
16. Use u-turn crossover suitable for trucks wherever possible
17. Add emergency or farm vehicle crossover
18. Allow u-turns at left turn crossover
19. Allow left turns at u-turn crossover (e.g., line up u-turn crossover with side street or driveway)
20. Use flashing yellow arrow instead of red at crossover signal
21. Allow more right in-right out driveways

Choose "Do Nothing" Alternative If Necessary

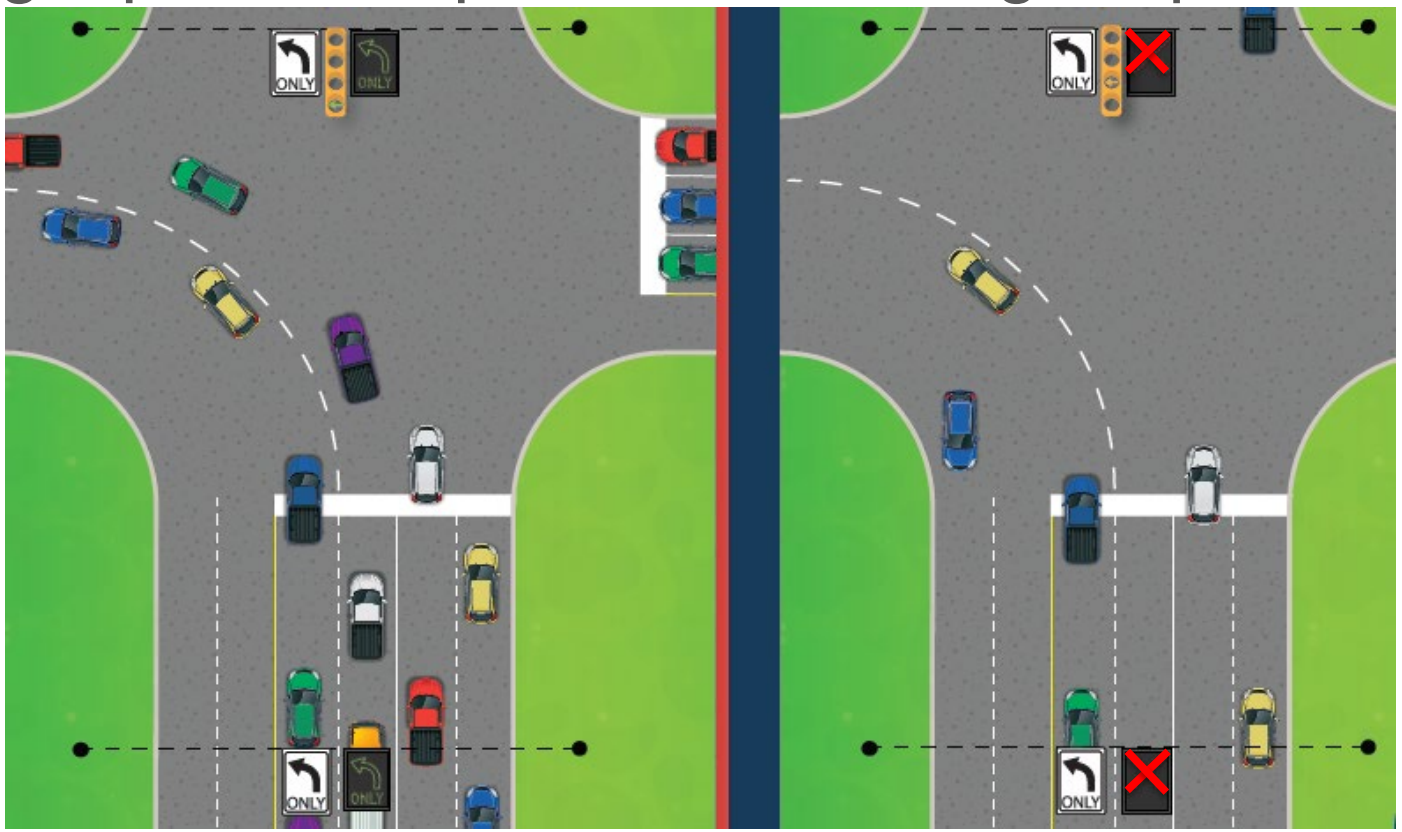
- It takes courage
- Don't build a lousy project
- Don't consider sunk costs
- Spend that money elsewhere
  - Lots of other worthy projects in pipeline
  - Prioritization prevents bait-and-switch
- This spot will be back a few years later

With Automated Vehicles

- Coming soon
  - Likely by design year
- Traffic engineering fundamentals will still be helpful
  - Reducing conflict points
  - Reducing signal phases
  - Using half signals
  - Guiding peds and bikes
- Can start to use variable and time-of-day lane controls
  - No problems with driver understanding

For Example, Dynamic Left Turn Intersection

- Dual protected during peak
- Single protected/permissive during off-peak



Research Needs

- Signals, signs, and markings
- Geometric design details
- More safety research, CMFs
  - Grade-separated intersections
- Safety surrogate methods
- Business impacts
- Intersection control evaluation (ICE) guidelines

Summary

- Intersections are important
- We know what works
- We have many alternatives
- Safety first, use SAFID as default
- Efficiency and other parameters matter too
- Choose the best alternative for each spot
- Use our strategies to overcome resistance
  - Opportunistic, research, education, PR, consistency, compromise, do nothing

Thank You!

- Let's go fix some traffic jams
  - Joe Hummer
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